COLLECTION OF ZERO-LIFT DRAG DATA ON BODIES OF REVOLUTION

FROM FREE-FLIGHT INVESTIGATIONS

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SUMMARY

This report presents a compilation of most of the zero-lift drag results obtained from free-flight measurements made by the Langley Pilotless Aircraft Research Division on fin-stabilized bodies of revolution. The data are arranged on standard forms, which also contain the significant geometrical factors. Supplementary data have been provided to facilitate the determination of the body pressure drags from the measured total drags. Summary plots and discussions have been included to provide a unified and broad picture of the effects of body geometry on zero-lift drag.

The Mach number range of the tests extends from 0.6 to approximately 2.0 and the Reynolds numbers based on body length from 2×10^6 to 100×10^6 .

INTRODUCTION

At the present time, the most accurate method of obtaining the zerolift drag at transonic and low supersonic Mach numbers of an arbitrarily shaped body of revolution is measurement by means of wind-tunnel or freeflight tests. The importance of accurate knowledge of zero lift has been increased by the usefulness of the "area rule" concept in the design of complete aircraft configurations, since this concept states that the drag of a complete aircraft configuration can be determined from its equivalent body of revolution.

The Langley Pilotless Aircraft Research Division has flown nearly 200 bodies of revolution of different sizes and shapes for the purpose of measuring their drag at zero lift. The results of many of these tests have been published in reports dealing with the systematic variations which they explored. However, many of these models were designed as equivalent bodies of revolution, and their drags have been published in the widely scattered reports dealing with the airplane configurations

NACA TN 4201 they represented. In view of the large amount of data available and of the comparative obscurity of a large part of it, it was felt that a collection of such data presented in a standard form would be of aid to the aircraft and missile designers.

It is hoped that this collection will be useful in several ways. The large number of shapes presented herein may allow the designer to estimate easily the drag of a desired shape by a simple comparison. Supplementary data and theoretical estimates have been provided to facilitate the determination of the body pressure drags from the measured total drags. Summary plots and discussions have been included to provide the user with a unified and broad picture of the effects of body geometry on zero lift drag.

SYMBOLS

1	length
d	maximum diameter
ı/a	fineness ratio
r/R	ratio of body radius at any station to maximum body radius
x/l	ratio of distance measured from apex of nose to total body length
S _b /A	ratio of body wetted area to body frontal area (actual values calculated from expression $\frac{CD_f}{C_f} = 4l/d \int_0^1 \frac{r}{R} d \frac{x}{l} \text{ which is correct relationship between friction coefficient } C_f \text{ based on wetted area and friction drag coefficient } CD_f \text{ based on body frontal area})$
S _f /A	ratio of fin wetted area to body frontal area
A _b /A	ratio of body base area to body frontal area
/ Фъ	body slope at $x/l = 1$ (slope is always negative but is expressed as positive)
R	Reynolds number based on body length, $\frac{\rho Ul}{\mu}$

free-stream density free-stream velocity U free-stream viscosity M free-stream Mach number drag coefficient based on body frontal area, CD Pressure - Free-stream pressure pressure coefficient, Cp PU2 Cf friction drag coefficient based on wetted area r' = r/R where R is maximum body radius $x' = x/l_{nose}$ or $x/l_{afterbody}$ rh' = rhase/R

TESTS

Most data of this report were obtained by the following procedure: A fin-stabilized model flying at or near zero lift was tracked with a CW Doppler radar unit as it decelerated through a speed range from supersonic Mach numbers to high subsonic Mach numbers. The resulting velocity time history was arithmetically differentiated to give a deceleration time history. Shortly before or after the flight, a record of the atmospheric properties (density, temperature, and wind velocity) was obtained from the flight of a radiosonde balloon. This record, together with a space-position time record of the flight, permitted the zero-lift drag coefficient to be calculated. The tests differ only in the method of launching the models into free flight and in the method of obtaining the altitude time history.

Rocket Model Tests

The rocket-test method is the propulsion of the models by rockets located in the model, or behind the model in the form of booster rockets which dropped away after burnout. In these tests the models were also

tracked by an NACA modified SCR-584 position radar tracking unit, the data of which were used to obtain the space-position time records used in the data reduction. In general, the rocket models were of a fair size: 5 to 8 inches in diameter and up to 12 feet in length. The data were obtained with the models at all altitudes up to over 50,000 feet and Mach numbers over 4. A few carried telemetering equipment and from these the total drag was also obtained from decelerometers and the base drag from pressure cells.

Helium-Gun Tests

The second technique, the helium-gun test, was the launching of small models (roughly 2 inches in diameter and 12 inches long) from a helium gun. The helium gun used to launch these models was a 24-foot smooth-bore barrel 6 inches in diameter attached by valves to a 100-cubic-foot tank of helium under a pressure of 200 pounds per square inch absolute. The models were ejected at Mach numbers up to 1.4. The space time histories of these models were calculated from the velocity-time data, and the data were reduced as before. A satisfactory check of the flight-path calculation method was made by tracking several models with the SCR-584 unit. The models were fired at an angle of 20° to the horizontal and never rose over an altitude of 2,000 feet.

Accuracy

Inasmuch as the tests have been made over a period of several years with continually varying techniques, it is difficult to assign a general figure for their accuracy. The velocimeter record is accurate to within 0.2 percent, and the derived accelerations, although the result of a short-time averaging process, are accurate to within 1 percent except in the region of the drag rise where it is possible for abrupt changes to be somewhat softened by the averaging process.

One approach to a value of accuracy is the comparison of the drag of identical models, since all the variable factors, inaccuracies in body ordinates, velocity measurement, atmospheric conditions, wind velocity, and data reduction are included.

From the variations shown by the models of configurations 8, 22, 27 to 30, 75 to 77, 106 to 109, 128, 139, and 151 reasonable limits of error for $\rm C_D$ and Mach number appear to be

 $\Delta C_D = \pm 0.01$

 $\Delta M = \pm 0.01$

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Another check on the accuracy is given by a comparison of the data of model 109 with a wind-tunnel test of an identical configuration. This comparison is shown in figure 1 and is quite good.

A third indication of the accuracy of the tests is given by a comparison of the nose pressure drags obtained from eight helium-gun models with values measured in a wind tunnel and calculated by second-order theory. The comparisons are quite close and indicate accuracy at least to the values quoted (see the discussion on nose drags in the section "Summary Curves").

PRESENTATION OF DATA

General Organization

With the thought in mind that the important product of these tests is the body pressure drag, the configurations are divided into two types - "smooth" and "bumpy" - and are presented in order of increasing fineness ratio. A smooth body is defined as one whose meridian increases without inflection points to a maximum and stays constant or decreases without inflection points to a minimum. All other bodies are considered to be bumpy. Since only the nose and afterbody¹ contribute to the pressure drag, the significant fineness ratio of the smooth bodies has been assumed to be that of the sum of the nose and afterbody. Such grouping assumes that the effects of the nose on the afterbody drag are of second order. Since such a division cannot, in general, be made for the bumpy bodies, they are presented in the order of their total fineness ratios. This classification by fineness ratio has the advantage of simplicity, and its usefulness is based on the general fact that this parameter is the most important single factor affecting body pressure drag.

The shape of the parts of the body is the other variable and since the assumption that the effect of shape is independent of fineness ratio appears to be useful, the body ordinates have been nondimensionalized and are presented in graphical form for each of the configurations. In order to utilize this assumption strictly, the individual parts should have been presented individually; however, this manner of presentation would have posed great problems for the bumpy bodies and was abandoned in favor of the simpler method used. This method has the advantage of enabling comparisons of bumpy and smooth bodies to be made by matching

The nose is herein defined as that part of the body up to the maximum diameter and the afterbody as that part from the maximum diameter to the base. Cylindrical sections of maximum diameter are considered as separate units and thus the sum of the values of $\it l/d$ of the nose and afterbody can be less than the total value of $\it l/d$ of the body.

their nondimensional ordinate curves and their total fineness ratios. Comparisons of the drag curves of such bodies allow estimates of the bumpiness of a bumpy body, that is, insofar as drag is concerned.

The basic data are supplemented by curves of friction, base, step, and fin drag (figs. 2 to 5). Summary curves of data from various systematic investigations are presented in figures 6 to 10. Some curves showing the general effect of body shape on drag appear in figures 11 to 15. The basic data are presented in figures 16 to 183 and are separated into two main groups. Figures 16 to 120 present the data for all the smooth bodies and the data for the bumpy bodies are presented in figures 121 to 138. (These data were compiled from refs. 1 to 16.) A particular configuration may be found quickly by reference to table I where the configurations are listed together with their distinguishing geometrical properties.

Presentation of Model Characteristics

Enough information appears in the drawing and graphical presentation of the ordinates to allow reconstruction of the model with reasonable accuracy. Many of the smooth bodies had analytical meridians of parabolic form or mixed parabolic and hemispherical form; this notation has been made in the figure. The following equations were used for parabolic noses and afterbodies, respectively,

$$r' = 2x' - x'^2$$

$$r' = 1 - (1 - r_b')x'^2$$

Pertinent fineness ratios, area ratios, and angles are given to allow quick comparisons of configurations. The type of test, rocket or helium gun, is also noted. All dimensions given in these figures are in inches.

Presentation of Data

Total zero-lift drag coefficients based on body frontal area and Reynolds number based on body length are presented for each model. The total-drag curves are curves faired through the original data points by the present author and thus may in some cases differ slightly from values previously published. For those configurations for which more than one model were flown the individual curves are labeled a, b, and

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so forth. For the models on which base pressures were measured, the base pressures are also presented.

For convenience, the friction drag calculated by the method of Van Driest (ref. 17) has been presented for each model. For cases in which the Reynolds numbers and the data appeared such that the flow over both the body and fins was turbulent, the points calculated were indicated by a square symbol of and connected with a dashed line. If the data appeared to be in the range in which the fin boundary layer may have been either laminar or turbulent, calculations were made for both conditions, and the points for both conditions were presented and left unconnected; thus, the circled points of represent the calculation for turbulent body flow plus laminar fin flow.

A word of warning is in order here: In the figures in which both symbols appear at the subsonic end of the Mach number scale and only the fully turbulent symbol is appears at the supersonic value, the Reynolds numbers are such that it is possible that transition from laminar to turbulent flow has occurred at some Mach number between the two extremes. This means that any pressure or wave drags derived by subtracting base, fin, and friction drag from the total drag can be in error by the amount of the difference between the turbulent and laminar fin friction drags. Configuration 158 (fig. 164) presents a case in point, although for this model the transition appears rather dramatically in the total-drag curve. This is unusual, and the change would not be at all apparent if the transition had occurred in the rapidly rising section of the drag curve.

Further discussion of friction drag is presented in the "Supplementary Data" section.

SUPPLEMENTARY DATA

This report presents a collection of total-drag curves for various bodies of revolution stabilized by fins. The usefulness of the data is largely determined by the information which can be obtained from these total drags concerning the values of the pressure or wave drags of the bodies alone (i.e., not influenced by the fins), since it is the value of this component of the supersonic drag that is always difficult and often impossible to calculate from theoretical considerations in the low supersonic speed ranges considered. In order to obtain the wave drag of the body alone from the test results, the friction, base, and fin pressure drags must be known or assumed.

The friction drag can be calculated accurately for most bodies. For many bodies, the base drag is negligible and the base drag for most of

the remaining bodies can be estimated accurately from empirical curves. The fin affects the drag in three ways - fin pressure drag due to fin induced pressures, pressure drag of the fin due to the body, and pressure drag on the body due to the fins. The value of the first component has in this report been either measured or calculated for most of the fins used. Values of the interference terms are, in general, not calculable. For the models of the present report, it appears reasonable to assume that the interference terms are negligible for most cases since the fins are extremely thin2.

The following sections provide the data necessary in the breakdown of the total-drag curves into their component parts.

Friction Drag

Figure 2 presents average flat-plate friction coefficients based on wetted area as functions of total Reynolds number for various Mach numbers. All values are for an insulated wall (no heat flow), which is correct for the wooden-surface models and is nearly correct for the models with metal surfaces and Mach numbers near 1. These values were used in the calculation of the friction drags shown on the data plots. The use of flatplate values for bodies of revolution is not exactly correct because of at least two factors - first, the difference between two- and threedimensional flow, and, second, the existence of velocities higher than free-stream velocity on the surface of the bodies. Both of these effects are functions of body fineness ratio, the effects being most in evidence at lower values of l/d. Reference 18 gives an approximate correction factor for the higher average velocities existing on bodies of revolution

as $\frac{(^{\text{C}}\text{D}_{\text{f}})_{\text{body of rev}}}{(^{\text{C}}\text{D}_{\text{f}})_{\text{flat plate}}} = 1 + \frac{0.5}{l/d}$ which is supposedly valid at Mach numbers

as high as 1. Both effects are apparently small for the bodies of this report.

The interference has been shown to be essentially zero by windtunnel tests of configuration 109 (see fig. 1) since the fin drag obtained by subtracting finned and unfinned results agreed exactly (except at M = 1) with fin drags obtained on special free-flight models on which the interference drag was zero by virtue of the cylindrical shape of the body. Since model 109 is of high fineness ratio this result cannot be applied generally. An attempt to measure fin interference was made with configurations 48 and 49. Although these bodies had low-fineness-ratio afterbodies on which the fin interference was expected to be large, the measured differences were small and in the opposite sense to that expected.

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Another assumption has been made in the calculation of the friction drag - namely, the bodies have been assumed to have either completely laminar or completely turbulent flow on the body and fins. This assumption may be erroneous for some of the models flying at Reynolds numbers from 1×10^6 to 5×10^6 and should be kept in mind in the analysis of such data. The only models for which this assumption is obviously wrong are models 104 and 105 (figs. 112 and 113), even though they flew at extremely high Reynolds numbers. These models are both models of the NACA RM-10 body, which has been extensively tested in wind tunnels (see refs. 13, 19, and 20). These models are more carefully finished than the majority and long runs of laminar flow (Reynolds numbers up to 40×10^6) have been detected on the body on some flights. Even more likely are long runs of laminar flow on the fins and since the fins of these models contribute nearly as much friction-drag area as the body, this would cause a large error in the calculations as made. With these considerations, if the pressure drag of this configuration is desired it would be best to obtain it from theory or the wind-tunnel results presented in references 13, 19, and 20. Note, however, that the base drags obtained from flight measurements should be the most accurate, since the tunnel measurements contain sting interference effects. References 13, 19, and 20 also give examples of the effects of Reynolds number, transition, and heat transfer on friction drag.

Base Pressure and Base Drag

Reference 21 contains excellent analysis and data on base pressure behind both two- and three-dimensional bodies when the boundary layer is turbulent ahead of the base and the Mach numbers are in the range considered in this report. The following discussion follows this reference.

Three-dimensional base drag. Figure 3 presents the base-pressure drag coefficients as a function of Mach number for a cylindrical after-body of infinite length (refs. 21 to 23). As mentioned in reference 21, the base pressure behind a cylindrical base can be influenced by flow conditions such as fin and nose pressure fields ahead of the base even when the boundary layer is turbulent well ahead of the base. For the bodies of the present report, such differences are believed to be small enough that the curve shown in figure 3 may be used, the possibility of such an error being always kept in mind, however, especially for subsonic speeds (see ref. 18, pp. 30 to 34).

Most of the bodies reported herein have afterbodies, that is, a base diameter which is smaller than the maximum diameter. The base drag of such bodies is discussed in reference 21; however, the method of evaluating such base pressures discussed therein is too complicated for the purposes of the present paper, since the value of the base drag is seldom

a very large percentage of the total drag for boattailed bodies. Some published wind-tunnel data on the base drag of conical afterbodies suggest the empirical expression

$$C_{D,base} = C_{D,cylinder base} \left(\frac{r_{base}}{R}\right)^3$$

Care must be taken in applying this equation at subsonic Mach numbers since it does not account for the possibility of negative base drags which can exist (ref. 24).

Two-dimensional base pressures. Figure 3 also presents base-pressure coefficients for a two-dimensional base from references 21 and 25. The data represent the base pressures behind slab wings. They are presented herein as an estimate of the pressures behind a rearward facing step on a body of revolution.

Pressures on a Forward Facing Step

Figure 23 presents the pressure coefficients required to separate the turbulent boundary layer in front of a step of several times the boundary-layer thickness. (See ref. 26.) It appears from page 52 of reference 18 that a pressure coefficient of $\rm C_p=0.41$ is valid at subsonic speeds as well as Mach 1. Again these essentially two-dimensional values are presented as estimates for the pressures ahead of forward facing steps on bodies of revolution.

Fin Pressure Drag

Figure 5 presents the pressure-drag coefficients based on the exposed plan-form area of the fin (note this is one-half the value of S_f/A given on model sheets) for most of the fins used in this report. Extreme accuracy has not been striven for or obtained, since in most cases the fin pressure drag is such a small part of the total drag that a 50-percent error in fin drag is of the order of the test accuracy.

The pressure drag of fin type A , which is used by the majority of the models, was measured by means of special helium-gun models. The drag of fin type B was measured by special rocket models, the data for which are presented in reference 27. The supersonic pressure drag thus obtained is so similar to that measured on

type A that they have been shown as one curve. The pressure drag of fin type C \(\int \) was estimated by reducing the drag rise of a 6-percent-thick delta wing of reference 27 (p. 47) by the square of the thickness ratios. The pressure drag of type D \(\int \) is simply the two-dimensional base pressure of figure 3 referred now to the fin plan-form area.

SUMMARY CURVES

Systematic Investigations

A majority of the smooth bodies of this report were flown in programs designed to investigate the results of systematic geometrical changes in the body shapes on zero-lift drag. Figures 6 to 10 present summary plots of total-drag coefficients for the most important of these investigations. These figures give a broad picture of the effect of the most important variables on the total body drag; that is, fineness ratio and maximum diameter location (fig. 6), nose shape and fineness ratio (figs. 7 to 9); (see also configurations 1 to 8) and afterbody fineness ratio and shape (fig. 10). Various other methods of correlating the data will be immediately apparent to the reader, but it is suggested that the original references be consulted before too elaborate an analysis is attempted, since the various data have been handled in more detail in these reports than in the present report.

Drag Analysis

The data of this report, together with data from wind-tunnel tests and theoretical results allow some general conclusions useful to designers to be drawn. Some of these conclusions are presented in the following paragraphs. The effects of nose and afterbody shape are discussed separately, after which a brief discussion is given of the effects of the shapes of complete bodies.

Nose drag. In the analysis of nose drag it is helpful to use one of the basic premises of this report, that is, that the effects of shape and fineness ratio may usefully be considered separately. The variation at M=1.4 of the nose pressure drag with l/d is presented in figure ll. The lower curve represents near minimum nose pressure drags. At

low values of l/d, the minimum curve was obtained by fairing through the flat-face value $\begin{pmatrix} C_D = 0.8C_{p} \\ \text{total} \end{pmatrix}$ and hemisphere values (ref. 28). Above l/d = 1.4 it was determined from second-order calculations (by the method of Van Dyke, ref. 29) of bodies defined by $r' = x'^{3/4}$ and $r' = \frac{2x' - \frac{3}{4} x'^{2}}{1\frac{1}{1}}$. Note that neither of these bodies has zero slope at

its maximum diameter. Since the calculations and experiment agree well for noses having l/d=3 (see fig. 12) a fair amount of confidence may be placed in the values shown. Second-order calculations are also shown for the parabolic nose $r'=2x'-x'^2$ used on so many of the models in this report. Taylor-McColl cone values are also shown for comparison.

Although 1/d is shown to be a powerful parameter, the effects of shape can be important as can be seen in figure 12. The results shown in this figure are particularly gratifying in that the values from freeflight and wind-tunnel tests and several theories are in marked agreement. As can be seen from this figure, there is no one minimum-drag shape for the entire Mach number range but several do well over the entire range. (Refs. 30 and 31 present the drags of many shapes not shown here.) Note these results are for l/d = 3 and the relative drags may change with 1/d. Data from reference 30 have been combined with the data of this report in part (b) of figure 12 to illustrate some general statements about the effect of nose geometry on drag. The drags of the $x^{1/4}$ and the ellipsoid show the high peak drag level and late peak drag Mach numbers characteristics of blunt nose bodies. The $x^{1/4}$ nose though not absolutely sharp (the cone could also have been used) shows the early drag rise and early sharp peak drag and the rapid decrease of drag with Mach number to be expected on sharp-nose bodies of revolution. The Von Karman nose which has the $x^{3/4}$ profile at its apex but which is blunter immediately behind the apex produces a drag variation with Mach number which incorporates the desirable features of both types of nose, that is, late drag rise, soft peak and low peak drag level, and decreasing supersonic drag. This result is perhaps not so surprising since this nose was designed (from linearized theory) for minimum drag for a given 1/d at low supersonic Mach numbers.

When these results are applied to the design of a complete body, it must be remembered that the interference drag of the nose on the after-body is also a function of nose shape. There are indications that the lowest drag shapes which do not have zero slope at their maximum diameter have higher interference drag potential than their smoother appearing brothers. (See the discussion entitled "Total body drag.")

Afterbody drag. The data of figure 10 have been analyzed to give the drags of the afterbodies caused by the pressures acting over the afterbodies and bases. (For details of the drag breakdowns, see ref. 6.) The results are presented for M=1.2 in figure 13. The data for the conical afterbodies are compared with the following semiempirical equation:

$$C_{D_{aft}} = \frac{0.001\theta + 0.00071\theta^{2}}{M} \left[1 - \left(\frac{r_{b}}{R} \right)^{n} \right] + C_{d_{b}} \left(\frac{r_{b}}{R} \right)^{3}$$
 (1)

where

$$n = 4$$
 $(M < 3.5)$
 $n = 3$ $(M > 3.5)$

 θ is the slope of the afterbody in degrees (used as positive, although actually always negative; not applicable for positive values of $\theta)$ and c_{db} is the base pressure drag of the cylinder (fig. 3). The first term

of the equation approximates the second-order theoretical values calculated by Jack (ref. 32) while the second term is a purely empirical approximation for the effect of base diameter ratio on the base pressure. In view of the inaccuracies inherent in both the experimental and the theoretical values (the theory, for instance, was calculated only for M > 1.5), the nearly exact agreement of the two shown in figure 13(a) is almost embarrassing and should be regarded as somewhat fortuitous. However, it is apparent, from the comparisons of this report with the second-order theory of reference 32 and from the comparisons of reference 6 with other theoretical calculations, that afterbody drags can be calculated reasonably accurately for afterbodies having maximum slopes of less than about 15°. At or above this degree of convergence large discrepancies may be expected (see ref. 6), theoretical calculations tending to overestimate the drag.

All the test results of both parabolic and conical afterbodies and the theoretical calculations lead to an extremely simple rule for selecting minimum drag afterbodies if a required value of 1/d is given. The center line in figure 13(b) represent conical afterbodies with a slope of 4.5° (or parabolic meridians with a base slope of 9°). The data points represent the parabolic afterbodies of figure 10; note also that the tangent to the parabolic base angle is always exactly twice that of the inscribed conical body. The minimum drag bodies all fall on this line. The fact that for a given value of 1/d the required ratio of

base diameter to maximum diameter is much less important at the higher values of l/d can be noted in figure 13(a), and is shown more graphically by the shaded area on the lower figure which shows the limits of configurations whose drags lie within about 10 percent of the minimum. The range of optimum conical angles indicated (3.5° to 6.5°) is of the same order (5° to 7°) as that used for some time by ballisticians for the drag reduction of bullets.

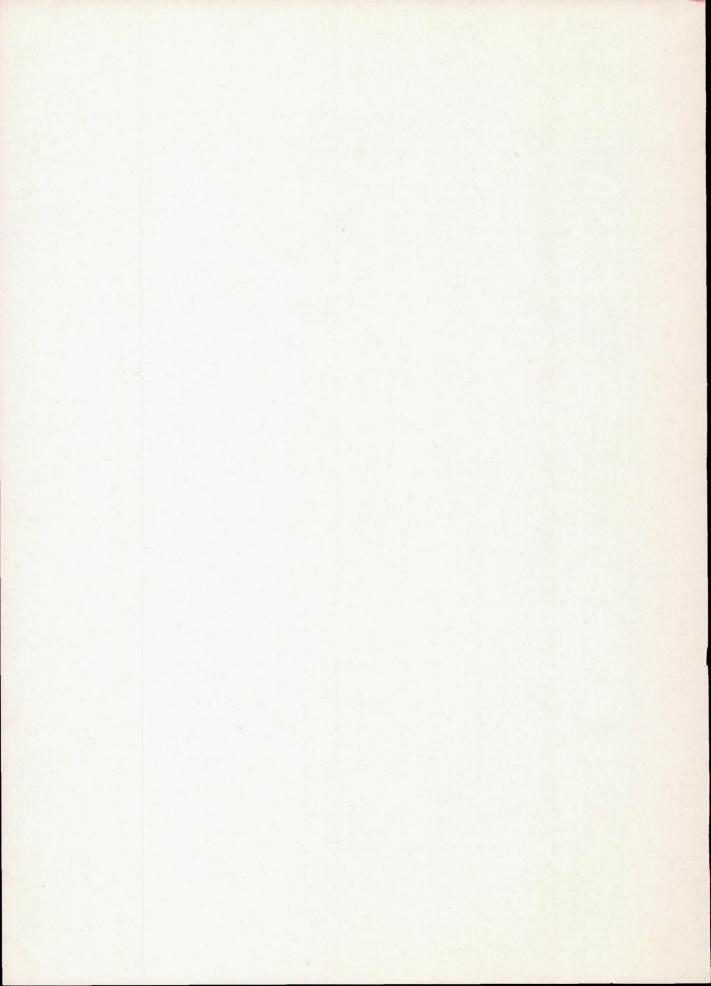
Total body drag. If the minimum afterbody drags at each value of l/d are taken, the resulting plot (fig. 14) may be said to represent a near minimum possible afterbody pressure drag for M = 1.2. A similar curve is presented for the nose drag and was obtained by fairing through the blunt nose values from configurations 1 to 7, through the minimum l/d=3 nose drag $\left(r'=x'^{1/2}\right)$ (fig. 12) and through the M = 1.4 values for the higher values of l/d (fig. 11). These curves are presented to give some practical boundaries, admittedly empirical and rough, to the minimum drag problem.

If the nose and afterbody minimum drags are added for bodies with their maximum diameter at their midpoints, the solid curve on figure 15 is obtained. If the same drags are added with care taken to position the maximum diameter at the most favorable position the dashed curve is obtained. (This position moves rapidly rearward from x/l = 0.55for l/d = 7 to x/l = 1 for l/d = 3 for the near minimum curves of figure 14; however, such values are extremely susceptible to small changes in level in either of the nose or afterbody drag curves and must only be considered as indicative of the trend.) Also, the drag rises $(\Delta C_D = C_{D_{total}} - C_{D_{friction}} - C_{D_{fin pressure}})$ for the smooth bodies of this report are plotted at the fineness ratio representing the sum of their nose and afterbody fineness ratios. Most of the bodies at low values of 1/d actually had cylindrical center sections and thus their interference drags were low. This must be kept in mind when the use of either of the empirical curves as minimum drag boundaries is contemplated. As an instance of this, compare the pressure drags of models 84 and 85 which are identical in shape $(r' = x'^{1/2})$, and fineness ratio of nose and afterbody, and differ only in the cylindrical center section of model 85. The higher pressure drag of model 84 must be attributed to interference of the nose on the afterbody. This interference drag seems high in comparison with the drag produced by the interaction of nose and afterbodies of the parabolic bodies of figure 6 which are indicated to be of the order of model 85 (and essentially zero) by a breakdown of their drags into component parts and a comparison of the pressure components with second-order theoretical calculations (ref. 29). It seems reasonable to assume that at total fineness ratios below 6, the effect of nose induced pressures on afterbody drag and perhaps more significantly NACA TN 4201 15

on base pressure (note large base diameter ratios of minimum drag afterbodies of fineness ratios less than 3 (fig. 13(b)), and see ref. 21 for some examples of such effects on base pressures) will be the important and perhaps the determining factors affecting both the shape of the body and the value of the drag of minimum drag designs.

While it is not a factor considered in the discussions of this report it must always be remembered that the dependence of drag on l/d is also a function of the friction coefficient, and that it is the increase of friction drag with l/d that limits the drag reduction due to increasing l/d.

Langley Aeronautical Laboratory,
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Langley Field, Va., September 3, 1957.



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TABLE I.- GEOMETRIC CHARACTERISTICS OF SMOOTH CONFIGURATIONS

configuration	l/d _{N+A}	1/d _{total}	l/d _{nose}	1/daft	S _b /A	S _f /A	A _b /A	θ_{b} , deg	Test	Reference	Figure
	0.50	12.00	0.50	0.00	49.00	6.36	1.00	0.00	Helium gun		16
1 - 8	0.50		1.38	2.33	28.30	11.00	.00	12.20	Helium gun		17
9	3.71	8.57		2.70	25.20	6.40	.00	68.00	Helium gun		18
10	4.62	7.70	1.92	1.14	39.30	11.00	.45	8.00	Rocket	1	19
11	4.64	11.20	3.50	2.83	22.40	11.00	.00	15.70	Helium gun		20
12	4.85	7.15	2.02	2.00	51.50	24.60	.52	4.02	Helium gun	2	21
13	4.98	13.47	2.98	2.00	51.30	24.60	.52	4.02	Helium gun	2	22
14	4.98	13.47	2.98		13.60	11.00	.00	18.80	Helium gun		23
15	5.00	5.00	2.00	3.00		11.00	.00	11.90	Helium gun		24
16	5.00	5.00	2.00	3.00	13.30	11.00	.00	12.70	Helium gun		25
17	5.00	7.78	2.00	3.00	25.00	11.00	.00	90.00	Helium gun		26
18	5.10	5.10	1.92	3.18	14.60	24.60	.52	4.02	Rocket	3	27
19	5.20	13.70	3.20	2.00	51.00	24.60	.52	4.02	Helium gun	2	28
20	5.20	13.70	3.20	2.00	51.00		.00	15.60	Helium gun		29
21	5.34	9.51	2.67	2.67	30.60	11.00		-5.00	Helium gun		30
22	5.70	5.70	5.70	.00	11.40	.00	1.00	4.02	Helium gun	2	31
23	5.79	14.29	3.79	2.00	51.90	24.60	.52		Rocket	14	32
24	5.84	5.84	.50	5.34	19.00	11.00	.19	7.00	Rocket		33
25	5.84	12.90	3.10	2.74	51.80	12.40	.25	18.60			33 34
26	6.00	8.78	3.00	3.00	26.20	11.00	.00	12.90	Helium gun		35
27	6.04	6.04	1.21	4.83	19.16	11.00	.19	9.20	Rocket	5	35
28	6.04	6.04	4.83	1.21	16.84	11.00	.19	25.00	Rocket		37
29	6.04	6.04	2.42	3.62	18.39	11.00	.19	8.80	Rocket	5	20
30	6.04	6.04	3.62	2.42	17.64	11.00	.19	13.00	Rocket	5	38
31	6.04	6.04	3.71	2.33	17.60	11.00	.37	6.10	Helium gun		39
32	6.08	9.60	5.01	1.07	31.60	12.30	.69	5.45	Helium gun		
	6.10	14.60	4.10	2.00	52.30	24.60	.52	4.02	Helium gun	3	4]
33 34	6.10	14.60	4.10	2.00	52.30	24.60	.52	4.02	Rocket	3	42
24	6.42	9.32	2.98	3.44	30.20	11.00	.00	13.30	Helium gun		43
35		15.00	4.50	2.00	52.60	24.60	.52	4.02	Rocket	3	44
36	6.50	10.87	2.71	3.80	35.60	12.82	.00	60.00	Helium gun		45
37 38	6.51		3.80	2.72	49.60	12.40	.25	17.40	Rocket		46
	6.52	13.90	2.80	4.20	19.00	11.00	.00	12.90	Helium gun		47
39 40	7.00	7:00			24.00	11.00	.19	7.00	Rocket	4	48
	7.16	7.16	1.81	5.35	24.20	11.00	.19	7.00	Rocket	4	49
41	7.30	7.30	1.95	5.35	25.60	11.00	.00	90.00	Helium gun		50

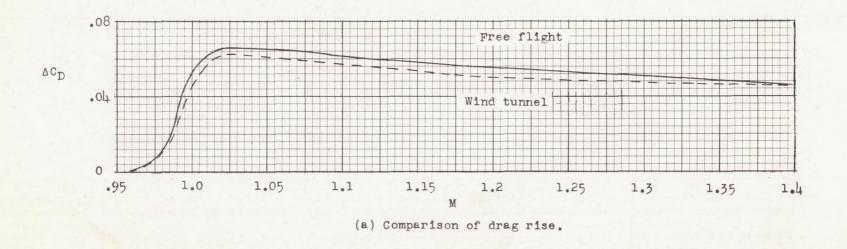
TABLE I.- GEOMETRIC CHARACTERISTICS OF SMOOTH CONFIGURATIONS - Continued

Configuration	l/d _{N+A}	l/dtotal	l/d _{nose}	l/daft	S _b /A	S _f /A	A _b /A	θ _b , deg	Test	Reference	Figure
43	7.35	7.35	2.00	5.35	22.70	11.00	0.19	6.00	Rocket	4	51
44	7.43	7.43	3.58	3.85	20.90	11.00	.00	15.00	Helium gun		52
	7.47	7.47	2.12	5.35	24.30	11.00	.19	6.00	Rocket	4	53
45 46	7.60	7.60	2.25	5.35	25.10	11.00	.19	7.00	Rocket	4	54
47	7.66	7.66	2.33	5.33	25.30	11.00	.19	7.00	Rocket	4	55
48	7.72	10.90	6.00	1.72	32.60	11.00	.00	2.90	Helium gun		56
49	7.78	11.50	6.00	1.78	35.50	11.00	.00	29.30	Helium gun	6	57
50	7.78	11.50	6.00	1.78	35.50	11.00	.00	29.30	Helium gun	6	58
51	7.80	11.08	3.42	4.38	34.40	11.00	.00	9.80	Helium gun		59
52	7.90	7.90	2.57	5.33	25.70	11.00	.19	7.00	Rocket	4	60
53	8.00	8.00	3.20	4.80	21.90	11.00	.00	8.50	Helium gun		61
53 54	8.00	8.00	4.66	3.44	23.16	5.80	.17	9.50	Helium gun		62
55	8.00	8.00	4.00	4.00	26.30	4.43	.00	14.00	Helium gun		63
55 56	8.00	12.00	3.00	5.00	36.38	11.00	.19	3.20	Helium gun	7	64
57	8.00	12.00	3.00	5.00	37.05	11.00	.19	3.20	Helium gun	7	65
57 58	8.00	12.00	3.00	5.00	38.35	11.00	.19	3.20	Helium gun	7	66
59	8.00	12.00	3.00	5.00	38.40	11.00	.19	3.20	Helium gun	7	67
60	8.00	12.00	3.00	5.00	38.78	11.00	.19	3.20	Helium gun	7	68
61	8.00	12.00	3.00	5.00	37.24	11.00	.19	3.20	Helium gun	7	69
62	8.00	12.00	3.00	5.00	37.58	11.00	.19	3.20	Helium gun	7	70
63	8.00	12.00	3.00	5.00	38.40	11.00	.19	3.20	Helium gun	-7	71
64	8.10	8.10	2.73	5.37	26.08	11.00	.19	7.00	Rocket	4	72
65	8.20	10.93	3.38	4.82	34.10	11.00	.00	9.00	Helium gun		73
66	8.30	8.30	2.96	5.34	26.50	11.00	.19	7.00	Rocket	14	74
67	8.33	9.02	3.27	5.06	26.60	9.20	.0384	23.00	Helium gun	8	75
68	8.44	8.44	3.20	5.24	24.90	5.45	.26	3.50	Rocket		76
69	8.50	8.50	3.60	4.90	26.30	9.74	.30	5.60	Rocket	9	77
70	8.50	8.50	3.16	5.34	26.80	11.00	.19	7.00	Rocket	4	78
71	8.60	8.60	5.59	3.01	25.70	5.20	.36	4.55	Rocket		79
72	8.65	8.65	3.28	5.37	27.30	11.00	.19	7.00	Rocket	4	80
73	8.81	8.81	4.04	4.77	28.80	11.00	.33	6.90	Helium gun		81
74	8.91	8.91	1.78	7.13	28.26	11.00	.19	6.50	Rocket	5	82
75	8.91	8.91	7.13	1.78	24.84	11.00	.19	18.30	Rocket	5	83
76	8.91	8.91	3.56	5.35	27.00	11.00	.19	6.00	Rocket	4 5	84
77	8.91	8.91	5.35	3.56	26.02	11.00	.19	10.20	Rocket	5	85
77 78	8.91	8.91	7.13	1.78	26.10	11.00	1.00	.00	Helium gun	6	86
10	0.71	0.71	1.1)	1.10	20.10	11.00	1.00		Lorana Bull		

Configuration	2/d _{N+A}	1/d _{total}	1/dnose	1/daft	S _b /A	S _f /A	A _b /A	θ _b , deg	Test	Reference	Figure
79	8.91	8.91	7.13	1.78	23.70	11.00	0.00	29.30	Helium gun	6	87
80	8.91	8.91	7.13	1.78	24.80	11.00	.19	17.50	Helium gun	6	88
81	8.91	8.91	7.13	1.78	25.40	11.00	.49	9.60	Helium gun	6	89
82	8.91	8.91	7.13	1.78	24.20	11.00	.19	9.00	Helium gun	6	90
83	8.91	8.91	7.13	1.78	25.10	11.00	.49	4.87	Helium gun	6	91
84	8.91	8.91	4.66	4.25	24.50	11.00	.09	9.70	Helium gun		92
85	8.91	12.50	4.66	4.25	38.80	11.00	.09	10.70	Helium gun		93
86	9.13	9.13	3.28	5.85	28.00	8.30	.008	30.00	Helium gun	8	94
87	9.38	9.38	3.63	5.75	28.00	6.40	.11	7.00	Rocket	10	95
88	9.54	9.54	4.20	5.34	28.60	6.40	.17	8.75	Rocket	10	96
89	10.00	10.00	4.00	6.00	30.88	11.40	.25	4.47	Rocket		97
90	10.00	10.00	4.73	5.27	29.60	17.76	.15	6.45	Rocket	11	98
91	10.54	10.54	5.38	5.16	34.40	11.00	.19	7.00	Rocket	14	99
92	10.63	10.63	7.13	3.50	33.00	11.00	1.00	.00	Helium gun	6	100
03	10.63	10.63	7.13	3.50	31.60	11.00	.49	5.40	Helium gun	6	101
93 94	10.63	10.63	7.13	3.50	30.06	11.00	.19	14.80	Helium gun	6	102
95	10.63	10.63	7.13	3.50	28.30	11.00	00	15.80	Helium gun	6	103
96	11.19	21.20	7.16	4.03	62.50	11.00	.19	4.00	Rocket	12	104
97	11.19	17.20	7.16	4.03	48.80	11.00	.19	4.00	Rocket	12	105
98	12.13	12.13	7.13	5.00	38.90	11.00	1.00	.00	Helium gun	6	106
99	12.13	12.13	7.13	5.00	36.90	11.00	.49	3.42	Helium gun	6	107
100	12.13	12.13	7.13	5.00	35.80	11.00	.49	1.70	Helium gun	6	108
101	12.13	12.13	7.13	5.00	33.30	11.00	.19	3.20	Helium gun	6	109
102	12.13	12.13	7.13	5.00	35.20	11.00	.19	6.40	Helium gun	6	110
103	12.13	12.13	7.13	5.00	32.20	11.00	.00	11.70	Helium gun	6	111
104	12.20	12.20	7.50	4.70	36.30	30.80	.364	7.60	Rocket		112
105	12.20	12.20	7.50	4.70	36.30	30.80	.364	7.60	Rocket		113
106	12.50	12.50	2.50	10.00	39.65	11.00	.19	3.20	Rocket	5	114
107	12.50	12.50	10.00	2.50	34.85	11.00	.19	12.60	Rocket	5	115
108	12.50	12.50	5.00	7.50	38.10	11.00	.19	4.30	Rocket	5	116
109	12.50	12.50	7.50	5.00	36.50	11.00	.19	6.40	Rocket	5	117
110	12.50	12.50	6.25	6.25	33.40	11.00	.00	90.00	Helium gun		118
111	17.78	17.78	10.65	7.10	52.00	11.00	.19	4.60	Rocket	12	119
112	24.50	24.50	14.70	9.80	71.60	11.00	1.19	3.30	Rocket	12	120

TABLE II.- GEOMETRIC CHARACTERISTICS OF BUMPY CONFIGURATIONS

Configuration 1/4total Sh/A Sh/A Sh, A Sh,		Q	1 - /-				*			
1115	-		1/d _{total}	S _b /A	S _f /A	A _b /A	θ _b , deg	Test	Reference	Figure
117 5.26 24.79 11.64 .14 23.90 18.21 20.19 11.86 5.25 15.60 11.28 .25 17.30 11.18 21.25 17.30 11.26 11.25 11.20 5.45 14.10 6.28 .04 5.50 12.10 .17 20.20 12.10 .12 .13 .12 .13 .12 .13 .13 .12 .13		114}	3.67	12.40	0.00	1.00	-7.60	Helium gun		121
118										122
119								Helium gun		
120 5.45 14.10 6.28 .04 5.50 Enlium gun 126 122 5.68 16.60 11.60 11.70 12.00 .00 13.60 Hellium gun 128 123 6.66 17.75 12.00 .00 13.60 Hellium gun 128 123 6.66 17.79 9.22 .06 16.70 Hellium gun 128 125 6.84 18.20 10.76 .00 90.00 Hellium gun 129 125 6.84 18.20 10.76 .00 90.00 Hellium gun 130 126 6.86 21.15 12.20 .18 18.00 Hellium gun 131 126 6.86 21.15 12.20 .18 18.00 Hellium gun 132 127 6.95 19.90 11.64 .20 8.80 Hellium gun 132 127 6.96 21.27 11.80 .26 10.50 Hellium gun 135 128 6.98 21.16 11.80 .26 10.50 Hellium gun 135 135 135 7.08 19.40 15.00 .00 90.00 Hellium gun 135 135 7.08 19.40 15.00 .00 90.00 Hellium gun 136 135 7.08 19.60 5.56 .12 6.50 Hellium gun 137 136 135 7.14 20.26 9.90 .00 90.00 Hellium gun 137 135 7.14 20.26 9.90 .00 90.00 Hellium gun 138 135 7.14 20.26 9.90 .00 90.00 Hellium gun 136 137 7.70 18.80 11.95 .05 15.40 Hellium gun 140 137 7.70 18.80 11.95 .05 15.40 Hellium gun 141 136 137 7.70 18.80 11.95 .05 15.40 Hellium gun 142 137 7.70 18.80 11.95 .00 Hellium gun 142 137 7.70 18.80 11.95 .00 6.65 .08 5.00 Hellium gun 143										
122	-			14.10	6.28					
129							20.20	Helium gun		
124										
125 6.84 18.20 10.76 .00 90.00 18.1 mg un -1.32 126 6.86 21.15 12.20 1.8 18.00 1.64 .20 8.80 12.80 12.80 19.90 11.64 .20 8.80 18.00 18.1 mg un -1.32 128 6.96 21.27 11.80 .29 9.70 18.1 mg un -1.33 130 7.08 19.40 15.00 .00 90.00 18.1 mg un -1.33 130 7.08 19.40 15.00 .00 90.00 18.1 mg un -1.33 131 7.08 21.55 11.86 .20 11.50 11.30 18.1 mg un -1.33 132 7.08 19.60 5.56 .12 6.50 18.1 mg un 14.36 133 7.14 20.26 9.90 .00 90.00 18.1 mg un -1.33 134 7.35 21.70 11.70 .19 .00 18.1 mg un 1.36 138 7.75 21.90 11.50 .06 90.00 18.1 mg un -1.33 134 7.35 21.70 11.70 .19 .00 18.1 mg un .14 136 138 7.75 20.90 5.78 .20 26.50 13.38 7.76 21.54 11.00 .00 9.40 14.0 8.00 24.80 15.20 18 35.20 14.1 mg un .14 .15 .00 .00 9.40 15.00 15.40 16.50 15.40 16.1 mg un .14 14.1 mg un .14 14.1 mg un .14 14.1 mg un .14 .15 .1									March Alexand	
127				18.20						
128										
129										
130									1	
131										
135						.20				
134										138
135	-									
136		135								
138	130					.08		Helium gun		
139		138						Helium gun		
140 8.00 24.80 13.20 .18 33.20 Helium gun 146 141 8.05 20.70 9.00 .09 7.90 Helium gun 147 142 8.04 24.04 13.00 .23 12.60 Helium gun 148 143 8.07 25.75 4.12 .15 4.30 Helium gun 149 144 8.10 25.11 13.20 .18 21.50 Helium gun 150 145 8.10 25.08 13.20 .18 17.10 Helium gun 151 146 8.11 21.00 7.67 .09 5.00 Helium gun 152 147 8.12 25.40 13.20 .18 17.10 Helium gun 153 148 8.23 20.80 11.72 .00 16.80 Helium gun 153 149 8.27 24.00 10.90 .29 2.80 Helium gun 155 150 8.28 20.70 11.80 .06 15.00 Helium gun 156 151 8.40 25.00 7.88 .17 6.10 Helium gun 156 152 8.43 25.10 6.00 .17 6.10 Helium gun 157 153 8.48 23.76 12.62 .30 2.40 Helium gun 158 154 8.49 25.12 11.00 .00 7.40 Helium gun 158 155 8.52 23.40 11.50 .08 2.50 Helium gun 160 155 8.52 23.40 11.50 .08 2.50 Helium gun 161 156 8.57 25.70 9.70 .00 90.00 Helium gun 161 157 8.70 24.54 13.12 .20 12.10 Helium gun 163 161 8.92 24.10 11.50 .08 2.50 Helium gun 163 162 9.08 26.26 14.40 .16 9.10 Helium gun 166 163 9.09 24.40 11.50 .07 12.60 Helium gun 167 166 9.28 26.91 7.14 .21 12.30 Helium gun 167 168 9.09 24.40 11.50 .07 12.60 Helium gun 167 168 9.09 24.40 11.50 .07 12.60 Helium gun 167 169 164 9.10 25.55 11.64 .04 10.00 Helium gun 167 168 9.22 26.17 7.14 .20 4.55 Helium gun 167 169 164 9.10 25.55 11.64 .04 10.00 Helium gun 167 167 9.31 28.19 10.00 .21 4.60 Helium gun 167 168 9.31 28.19 10.00 .21 4.60 Helium gun 177 166 9.28 26.91 7.28 .20 4.06 Helium gun 177 167 170 10.00 27.40 11.00 .00 6.80 Helium gun 177 178 10.04 27.40 11.50 .00 90.00 Helium gun 177 179 10.04 30.40 11.00 .00 6.80 Helium gun 178 177 170 10.00 27.40 11.00 .00 Helium gun 179 178 11.70 10.00 29.80 11.00 .21 4.60 Helium gun 177 179 11.00 430.40 11.00 .00 6.80 Helium gun 178 177 11.00 11.00 12.80 11.00 .20 Helium gun 179 179 11.00 11.00 12.80 11.00 .00 18.90 Helium gun 179 179 11.00 12.80 11.00 11.00 .00 18.90 Helium gun 188									1	
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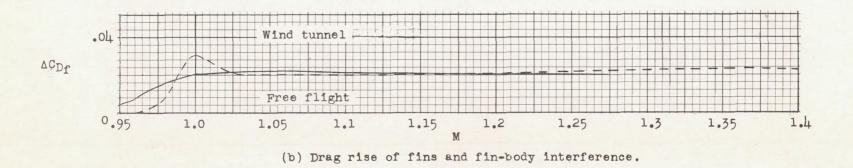


Figure 1.- Comparisons of data for model 109 obtained from wind-tunnel and free-flight tests.

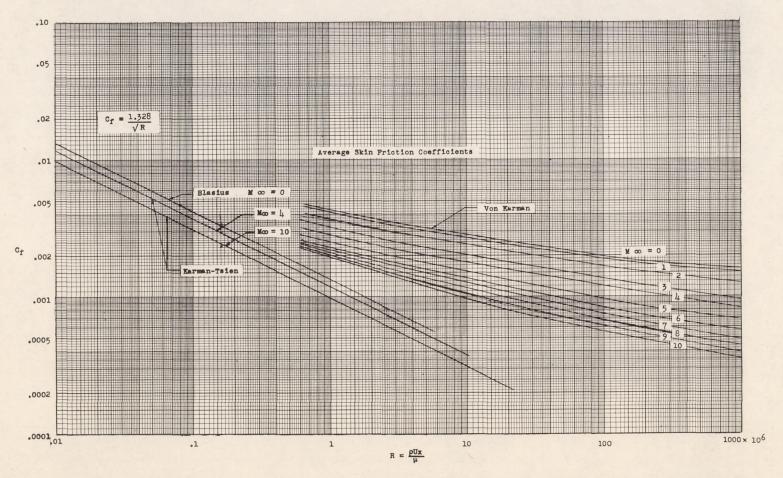


Figure 2.- Average skin-friction coefficients for flat plates based on wetted area.

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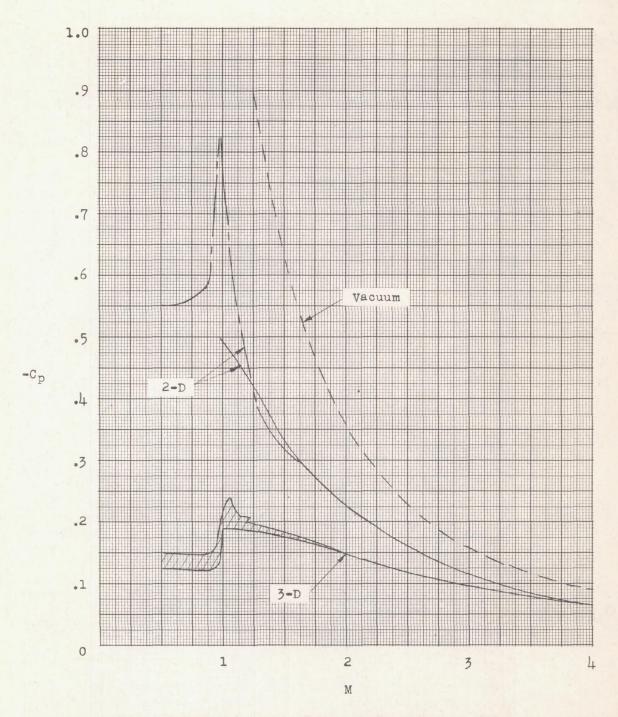


Figure 3.- Base-pressure coefficients behind two- and three-dimensional bodies for which flow is turbulent ahead of base.

27

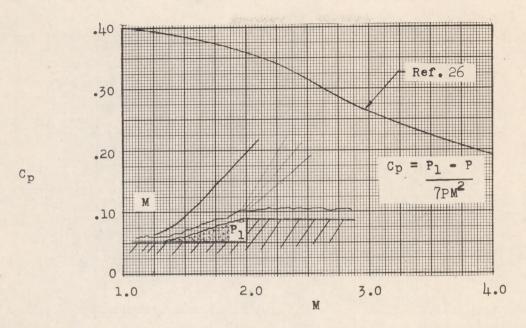


Figure 4.- Pressure coefficients on forward facing step for flow with turbulent boundary layer.

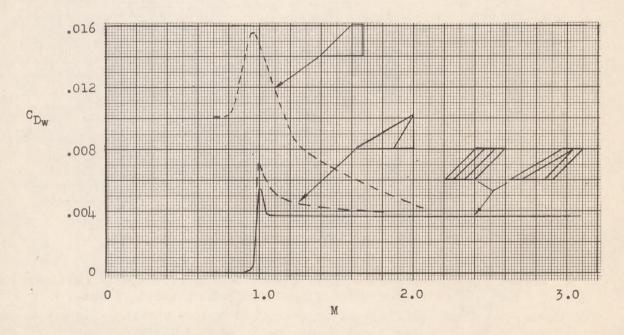


Figure 5.- Fin pressure drag coefficients (including base pressure) based on exposed fin area.

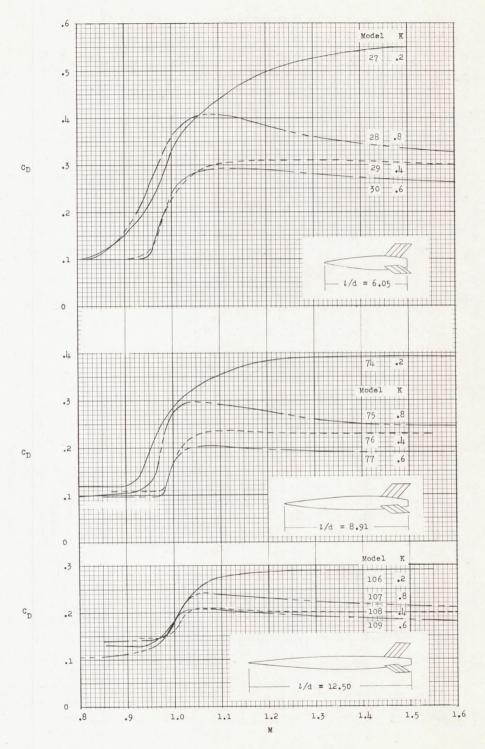


Figure 6.- Drag coefficients of parabolic bodies showing effects of fineness ratio and position of maximum diameter.

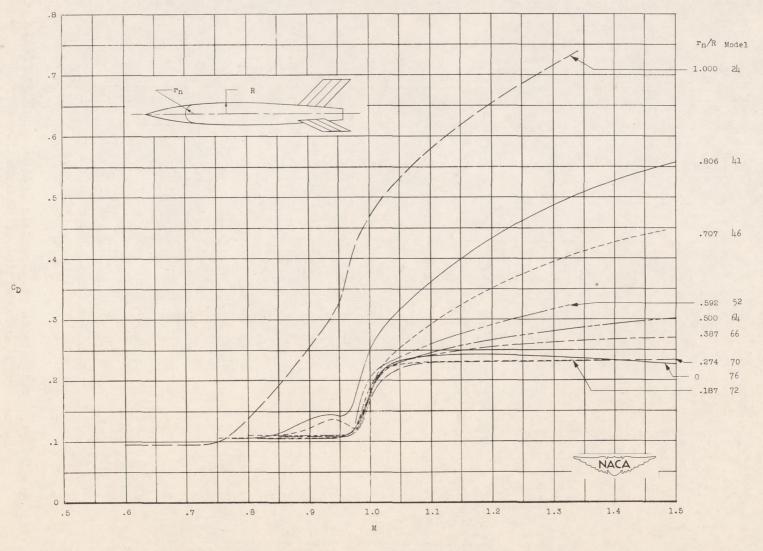


Figure 7.- Drag coefficient plotted against Mach number for configurations obtained by rounding off nose of parabolic body of fineness ratio 8.91.

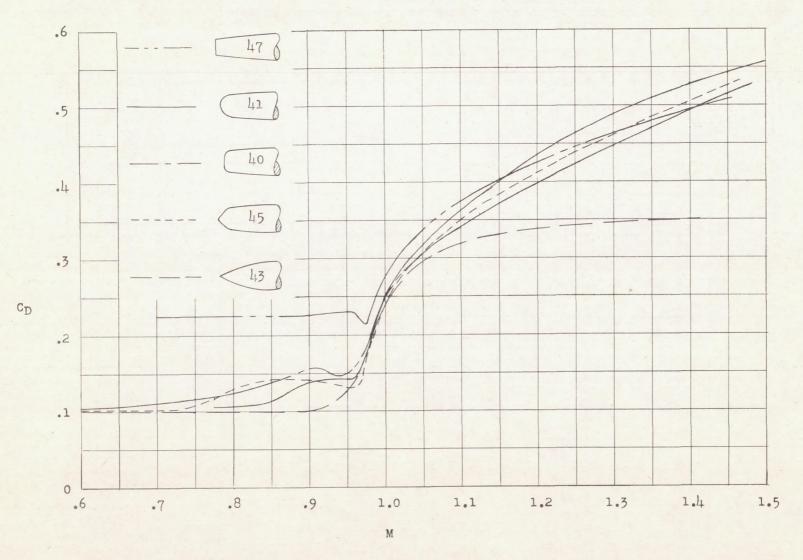


Figure 8.- Comparison of drag coefficients for five configurations having nose fineness ratios of about 2.

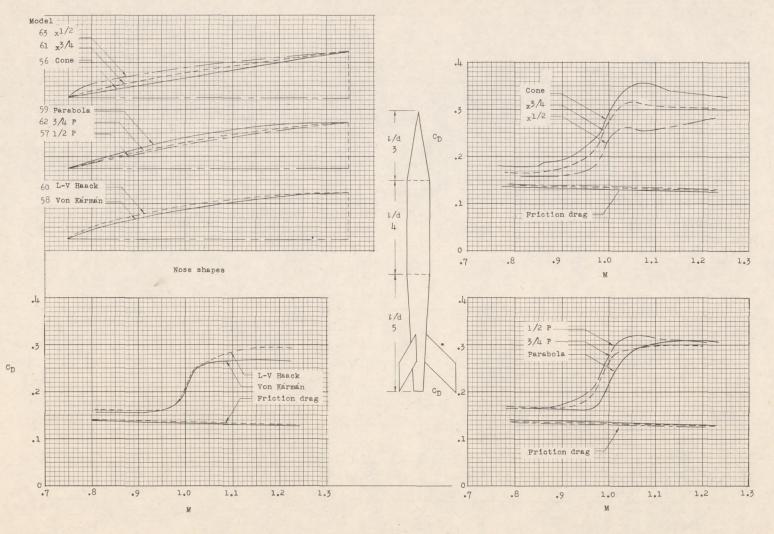


Figure 9.- Drag coefficients for eight bodies having fineness-ratio-3 noses of various shapes.

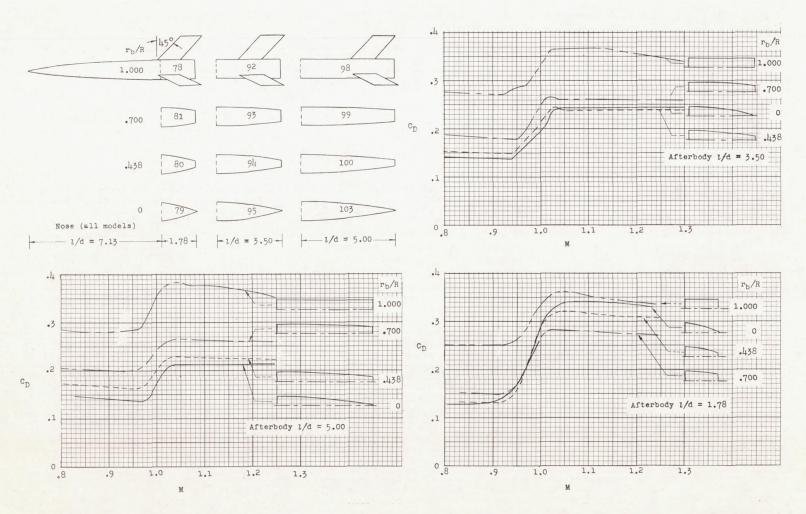


Figure 10.- Drag coefficients for 12 bodies having identical noses and different afterbodies.

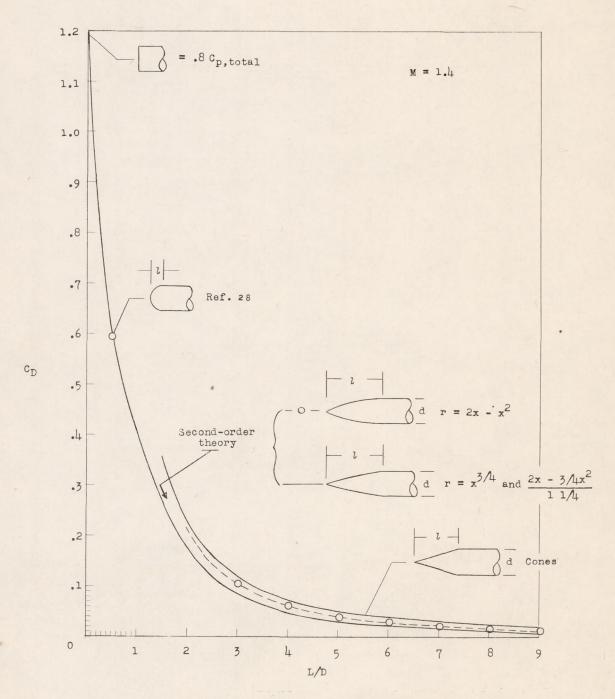
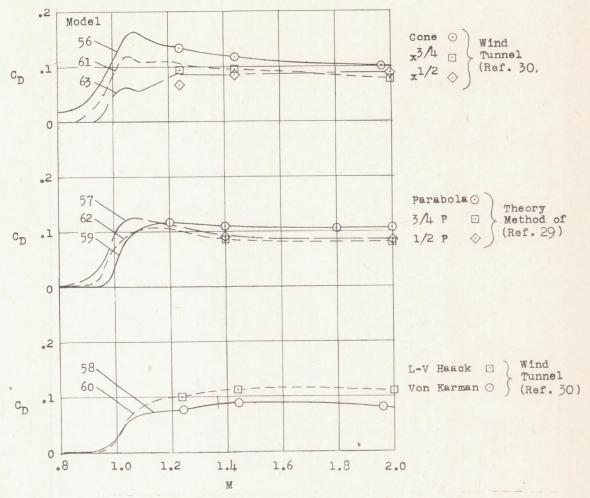
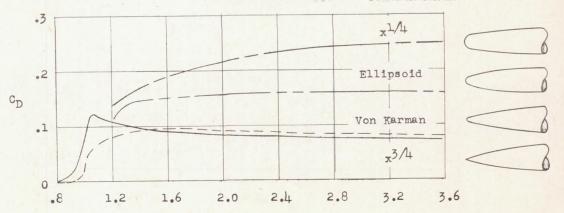


Figure 11.- Drag coefficients due to pressures on noses at M = 1.4.

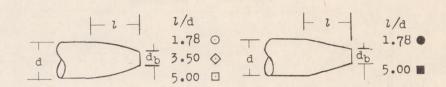


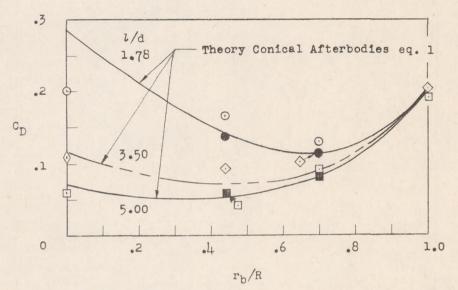
(a) Nose pressure drags of flight models compared with wind-tunnel results and theory.



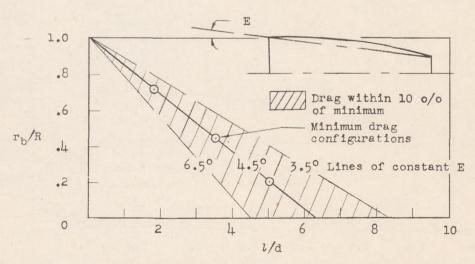
(b) Nose pressure drags from reference 30 showing general effects of nose shape on drag.

Figure 12.- Pressure drag of noses of fineness ratio 3.





(a) Experimental and Theoretical Afterbody Pressure + Base Drag at M = 1.2.



(b) Configurations for minimum afterbody drag at M = 1.2.

Figure 13. - Afterbody pressure drag at M = 1.2.

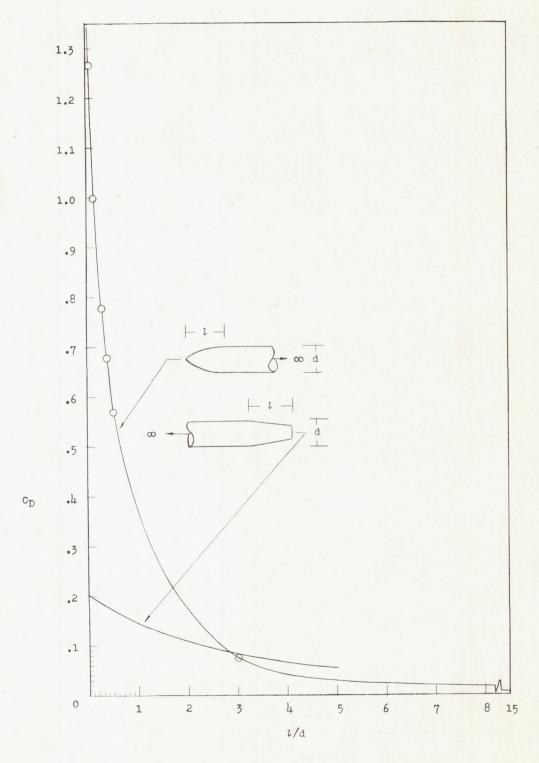


Figure 14.- Near-minimum pressure-drag coefficients at M = 1.2 for noses and afterbodies without interference.

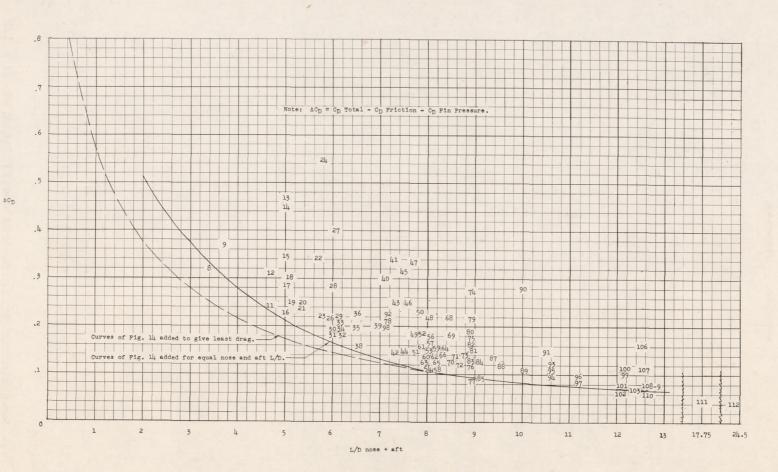
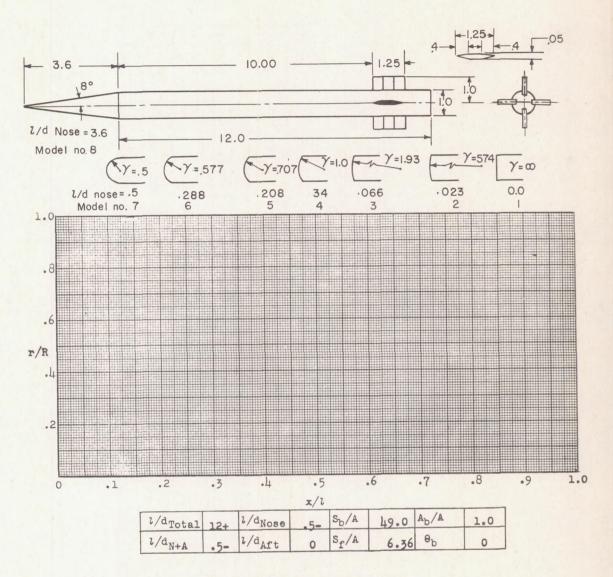


Figure 15.- M = 1.2 pressure drag coefficients.



Designation: 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8

Test: Helium Gun

Remarks: The abrupt drag variations at subsonic speeds are undoubtedly somewhat distorted by the data-reduction process; however, they are real as evidenced by similar phenomena noted in reference 18 (pp. 200 and 210).

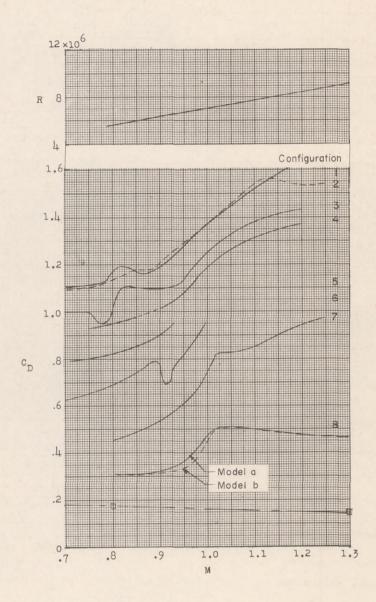


Figure 16.- Concluded.

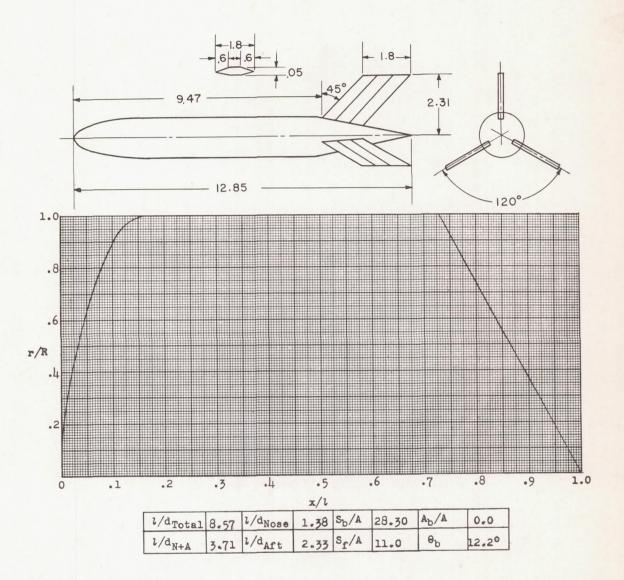


Figure 17.

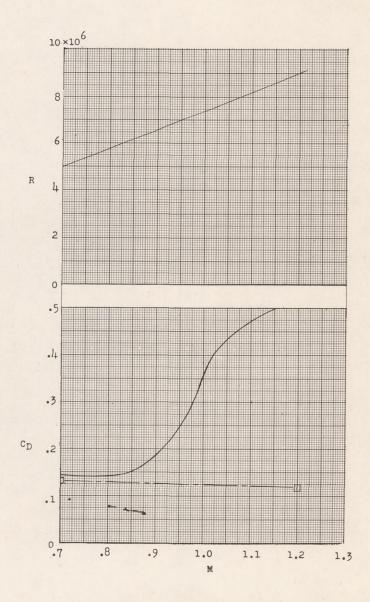
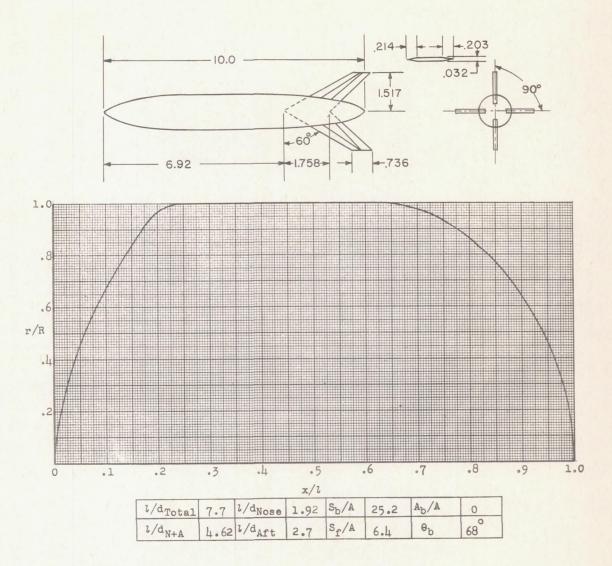


Figure 17.- Concluded.



Test: Helium Gun

Remarks: Nondimensional ordinates same as configuration 37 (fig. 45).

Figure 18.

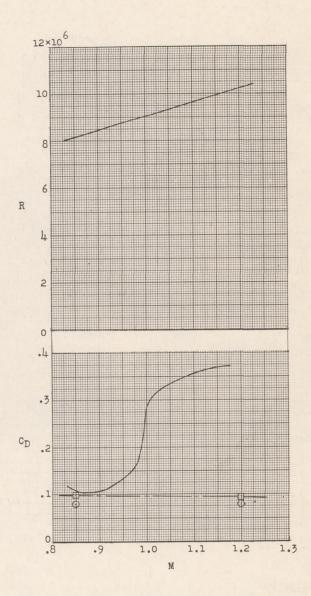
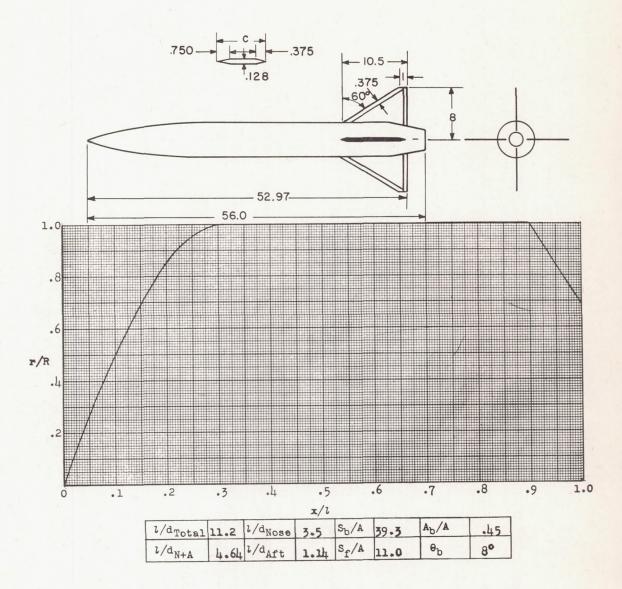


Figure 18.- Concluded.



Designation: ||

Test: Rocket

Figure 19.

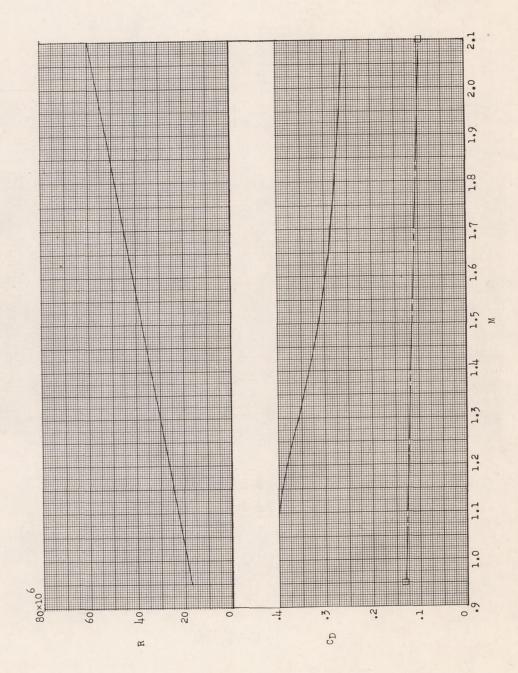


Figure 19.- Concluded.

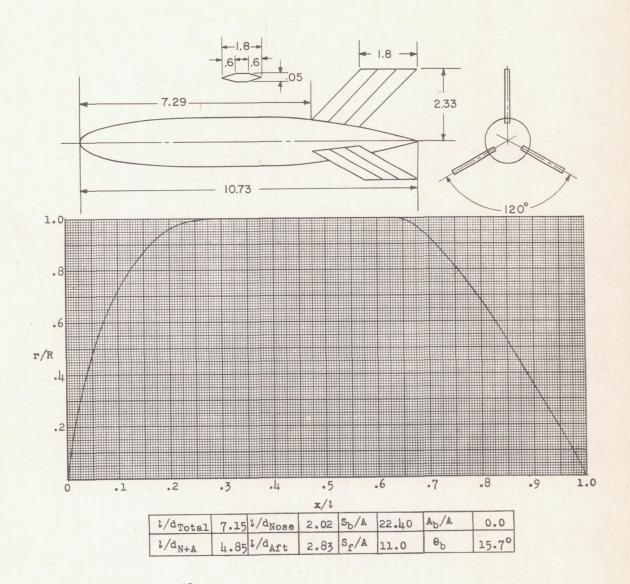


Figure 20.

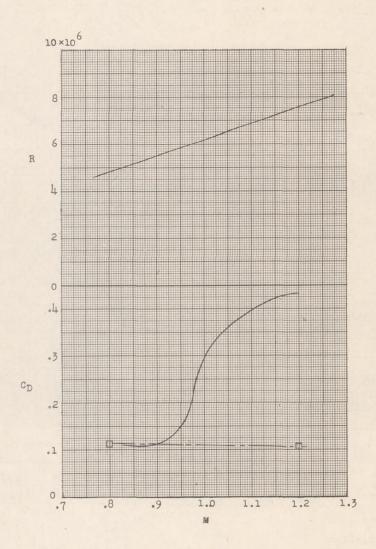


Figure 20. - Concluded.

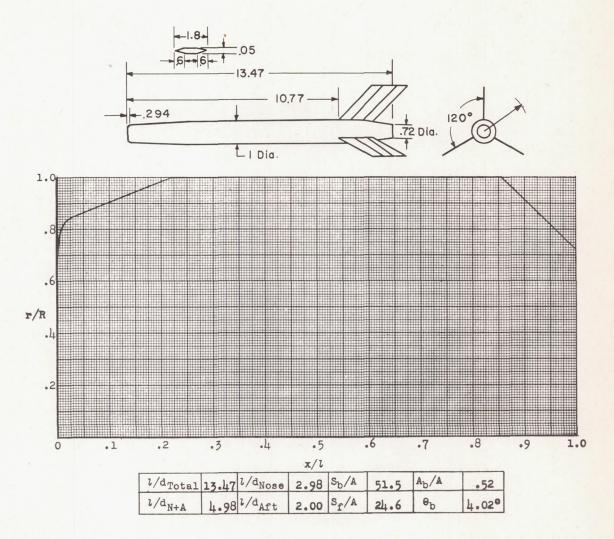


Figure 21.

49

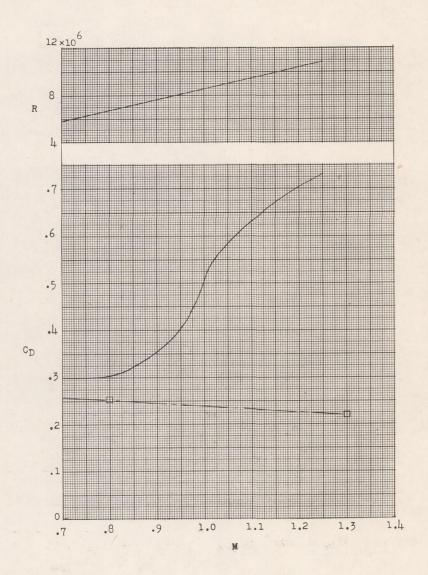


Figure 21. - Concluded.

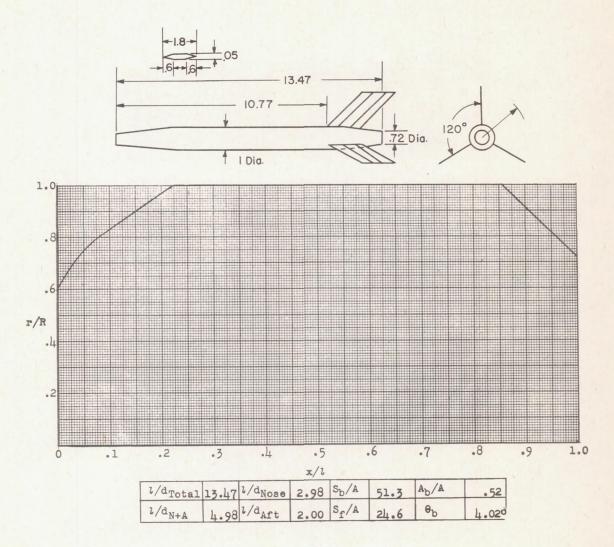


Figure 22.

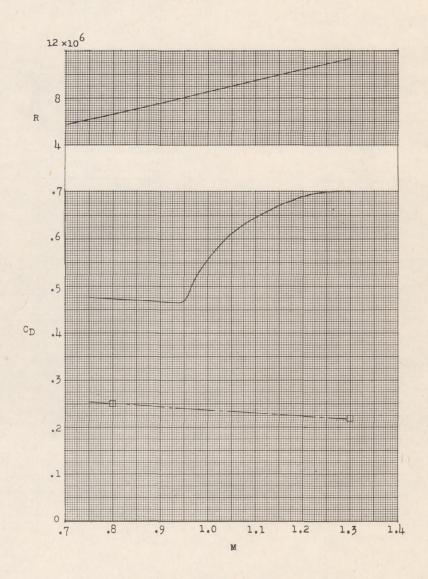


Figure 22. - Concluded.

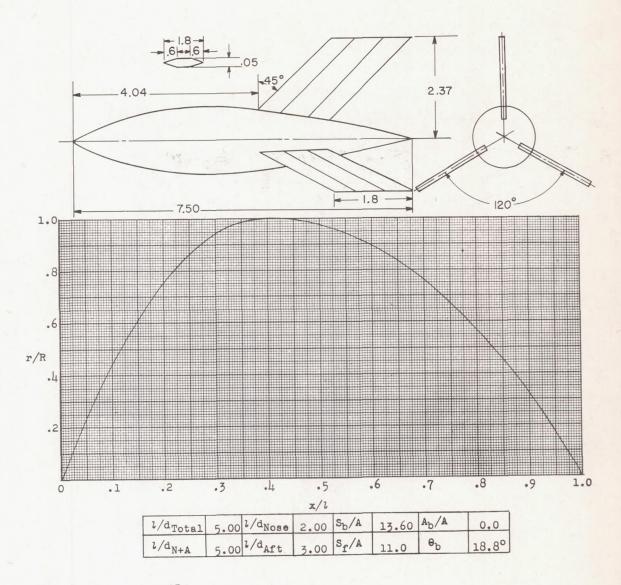


Figure 23.

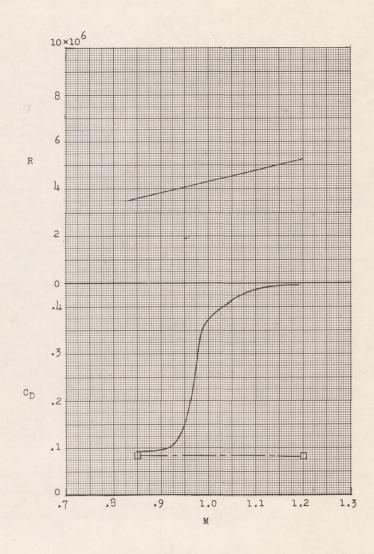
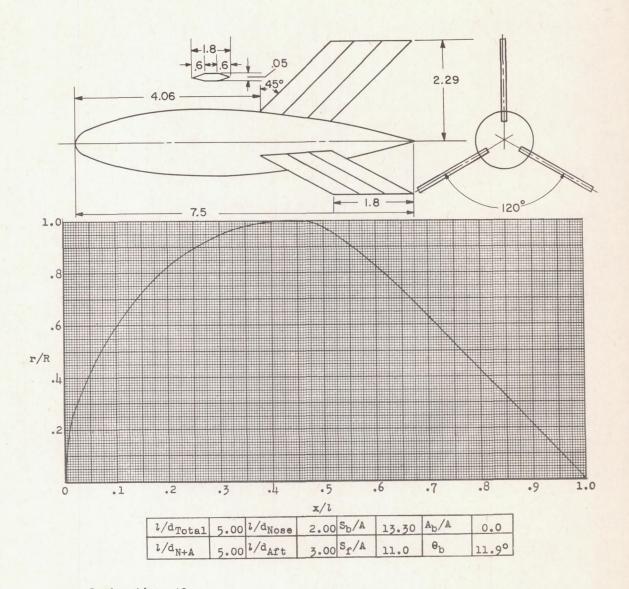


Figure 23.- Concluded.



Designation: 16

Test: Helium Gun

Figure 24.

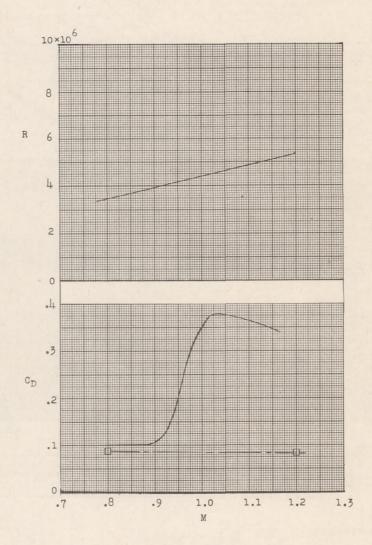
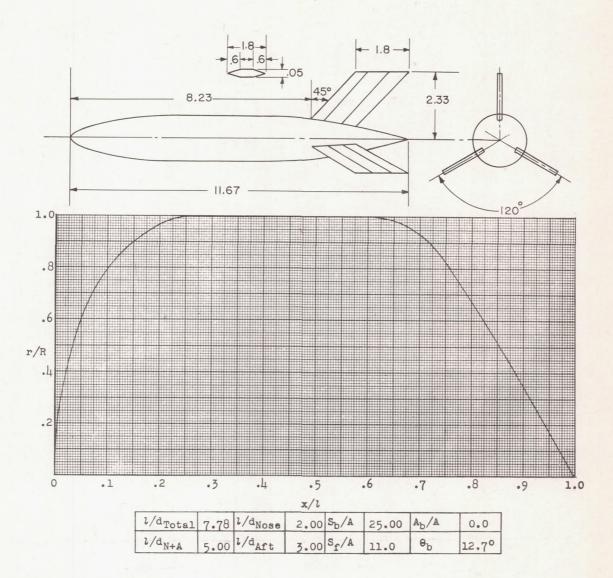


Figure 24.- Concluded.



Designation: 17

Test: Helium Gun

Figure 25.

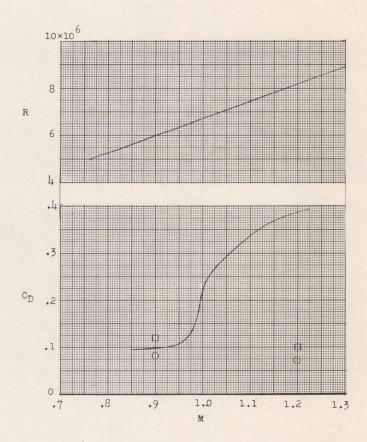


Figure 25. - Concluded.

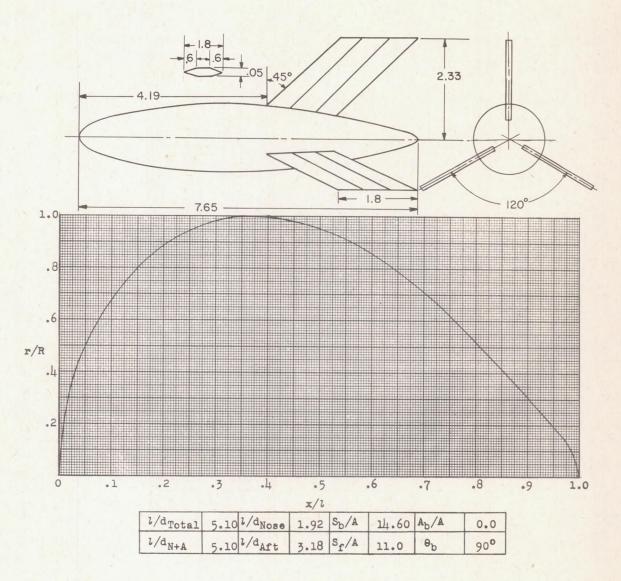


Figure 26.

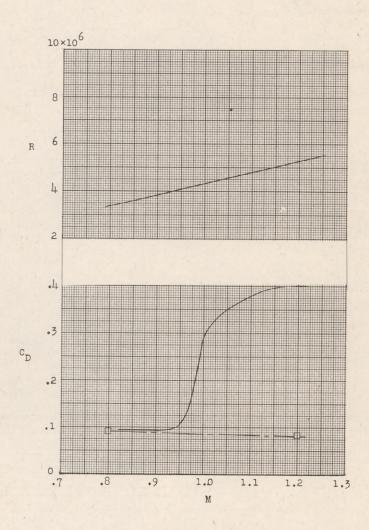
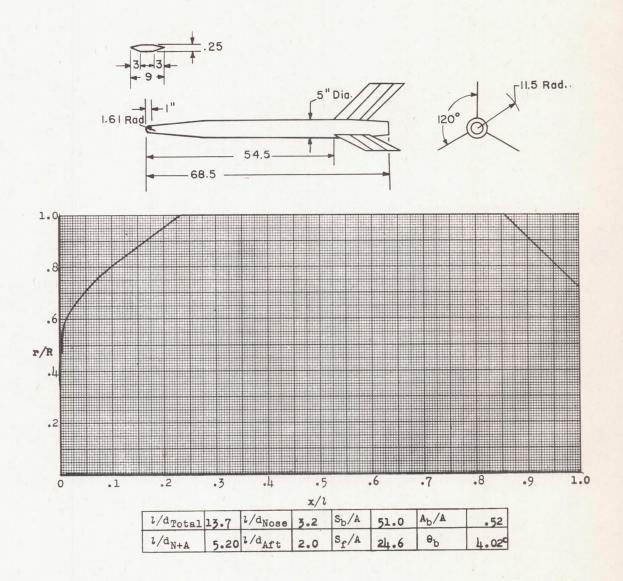


Figure 26. - Concluded.



Test: Rocket

Remarks: This model 5 times scale of model 20 (fig. 28).

Figure 27.

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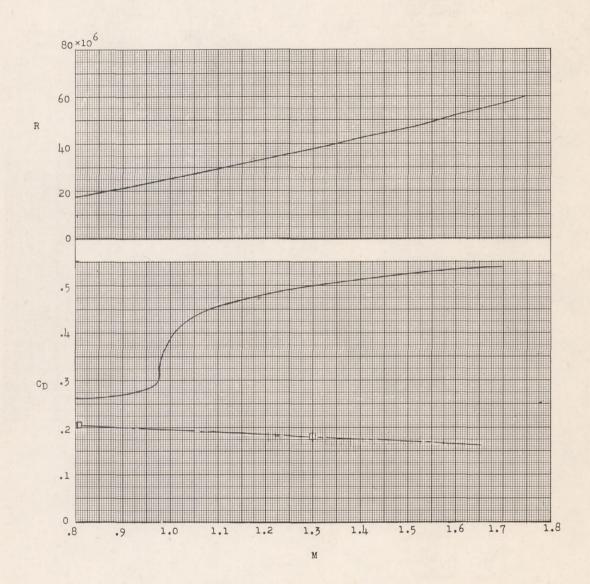
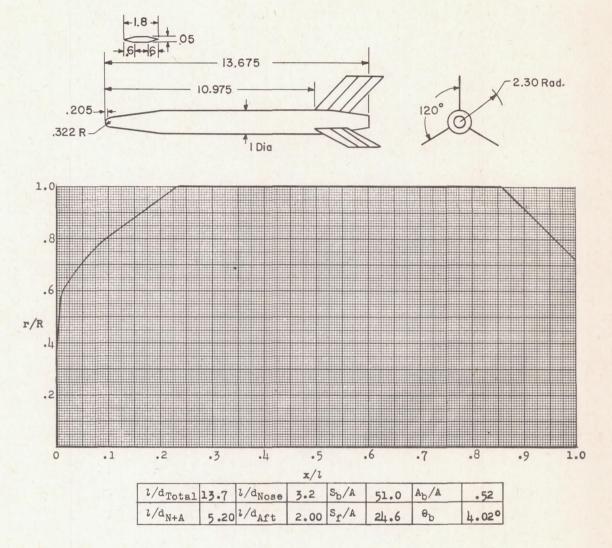


Figure 27.- Concluded.



Test: Helium Gun

Remarks: This model $\frac{1}{5}$ scale of model 19 (fig. 27).

Figure 28.

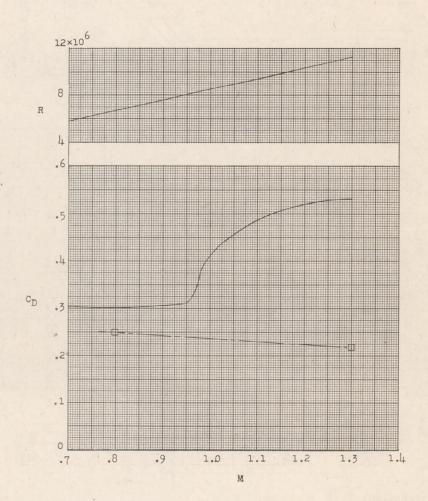


Figure 28.- Concluded.

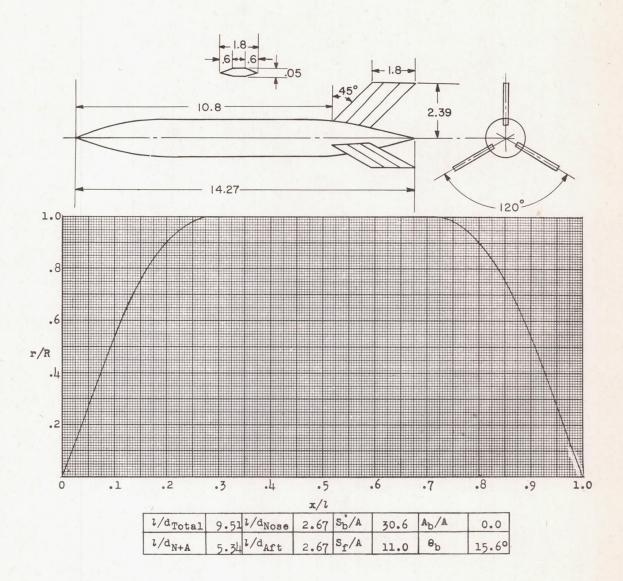


Figure 29.

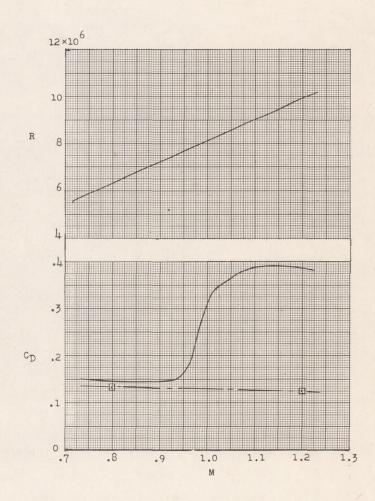
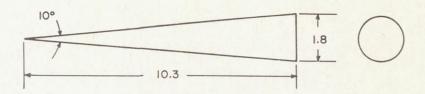


Figure 29. - Concluded.



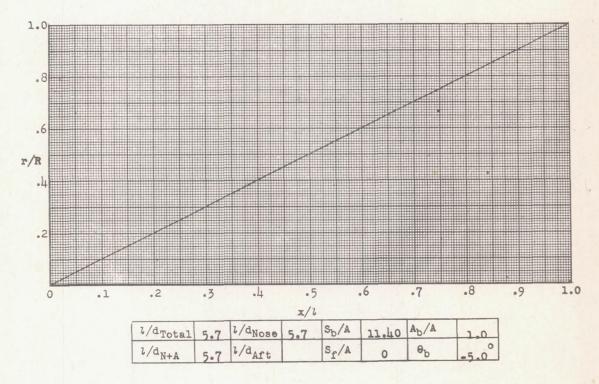


Figure 30.

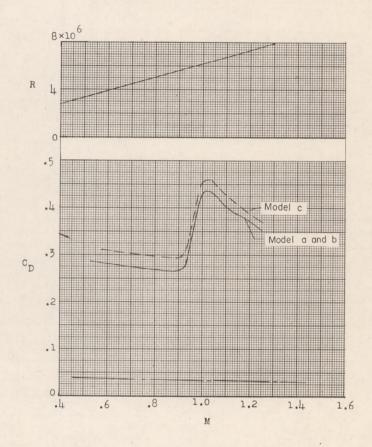


Figure 30. - Concluded.

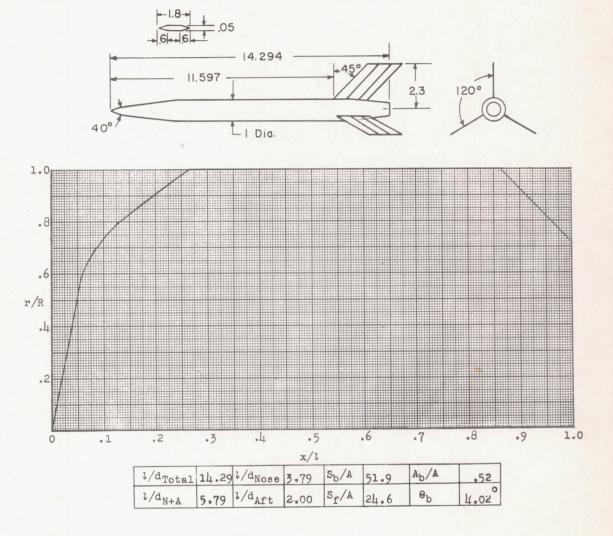


Figure 31.

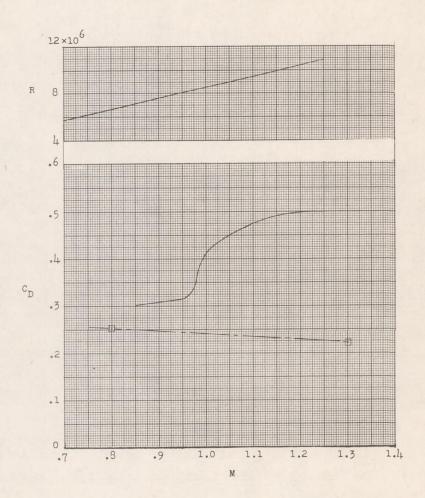
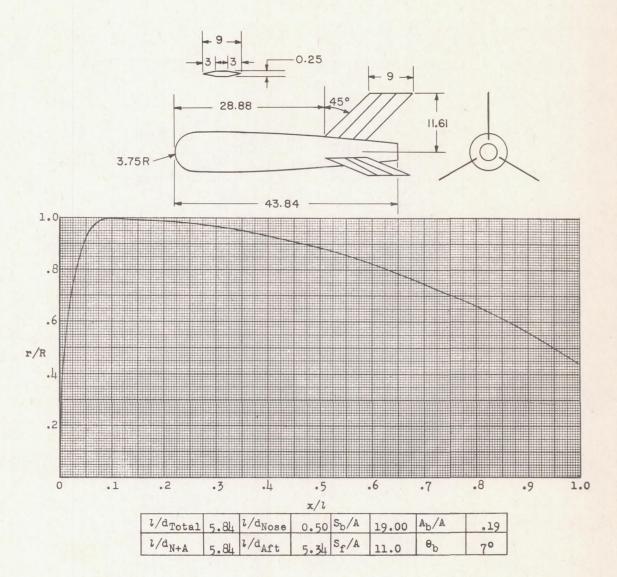


Figure 31.- Concluded.



Test: Rocket

Remarks: Hemispherical nose; parabolic afterbody.

Figure 32.

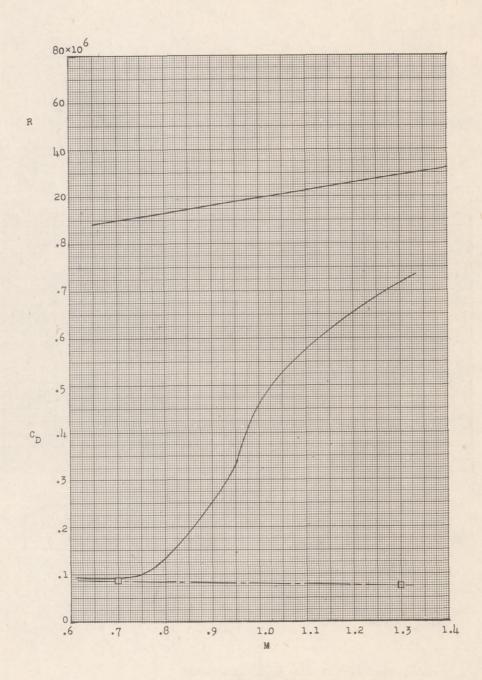
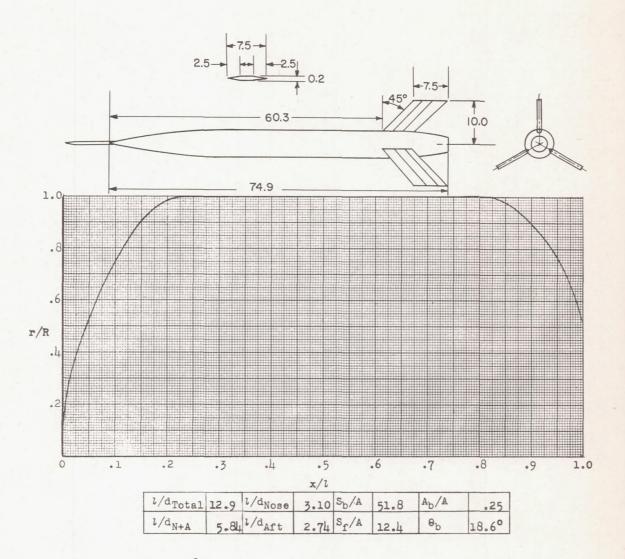


Figure 32. - Concluded.



Test: Rocket

Remarks: Sting may have some effect on friction drag but hardly any on pressure drag.

Figure 33.

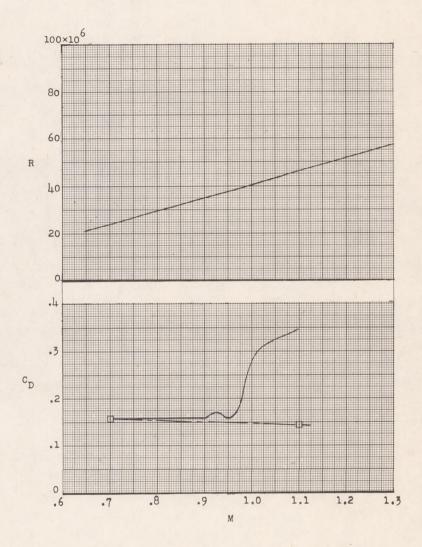


Figure 33. - Concluded.

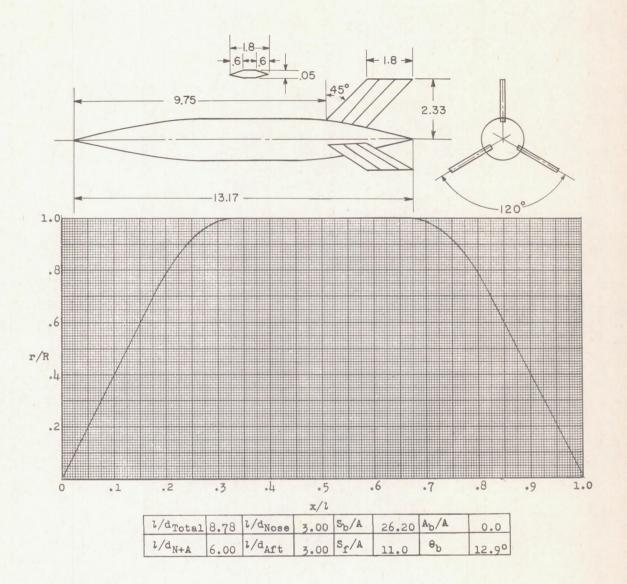


Figure 34.

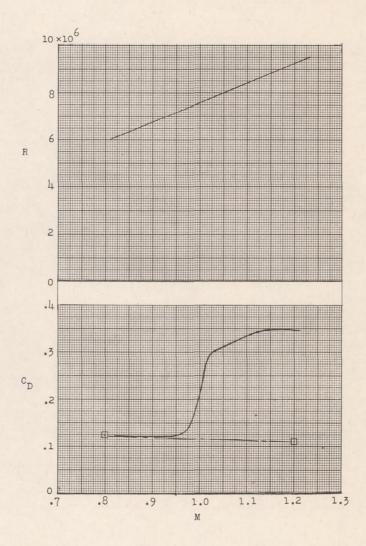
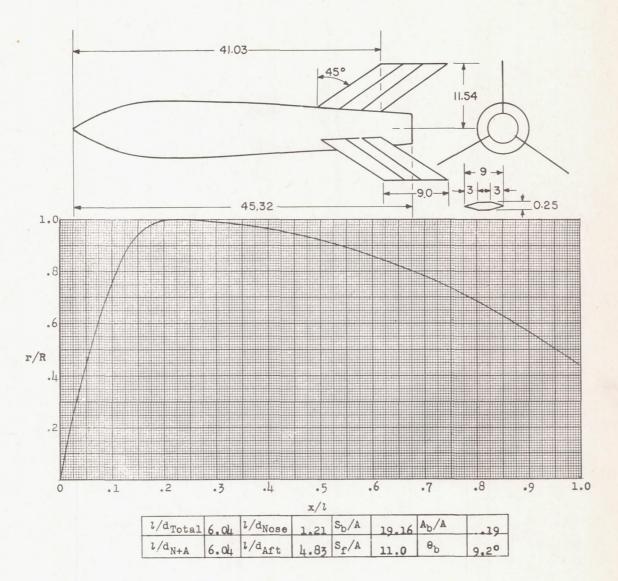


Figure 34. - Concluded.



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Test: Rocket

Figure 35.

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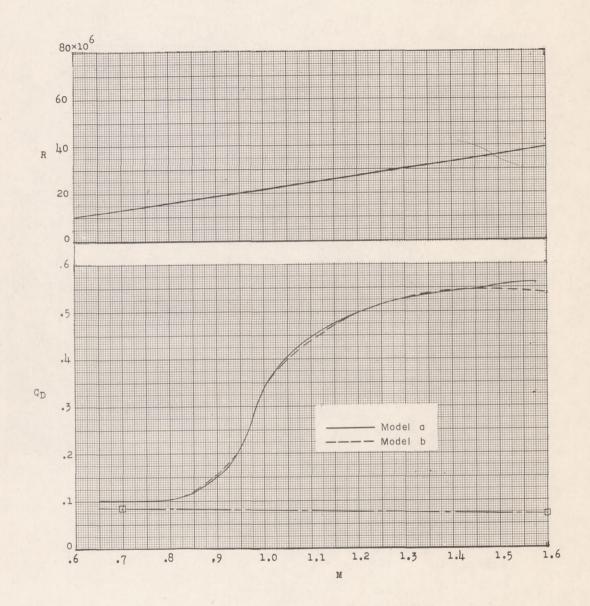
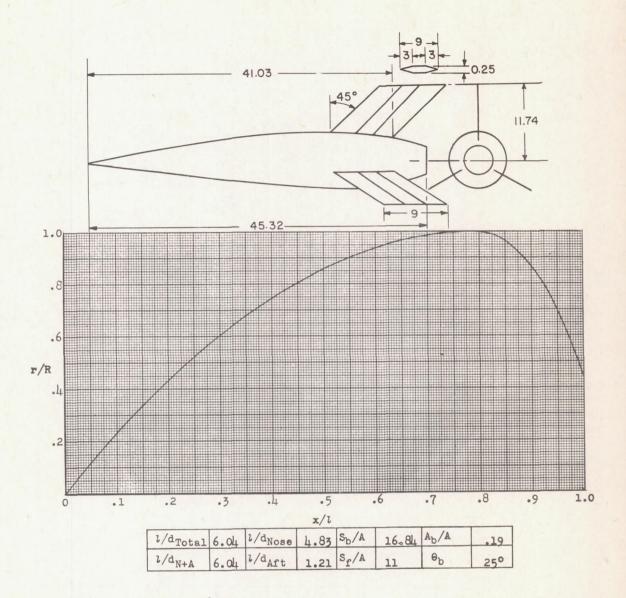


Figure 35.- Concluded.



Test: Rocket

Figure 36.

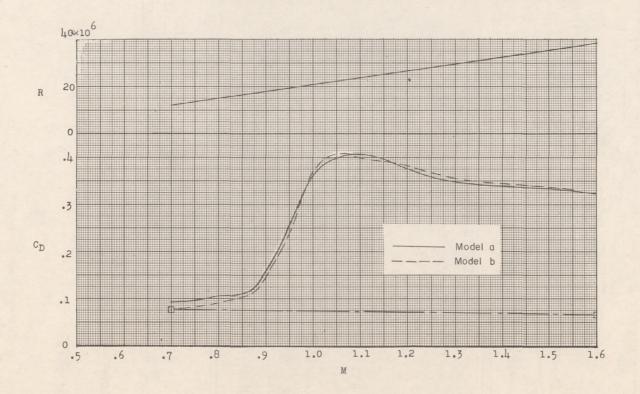
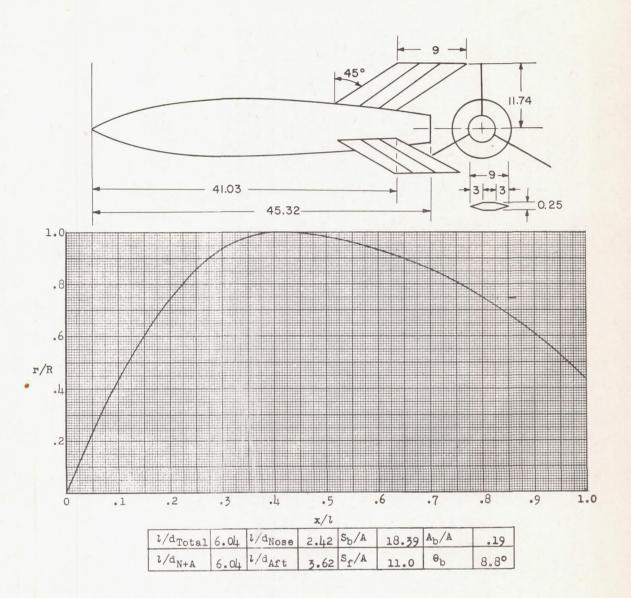


Figure 36.- Concluded.



Test: Rocket

Figure 37.

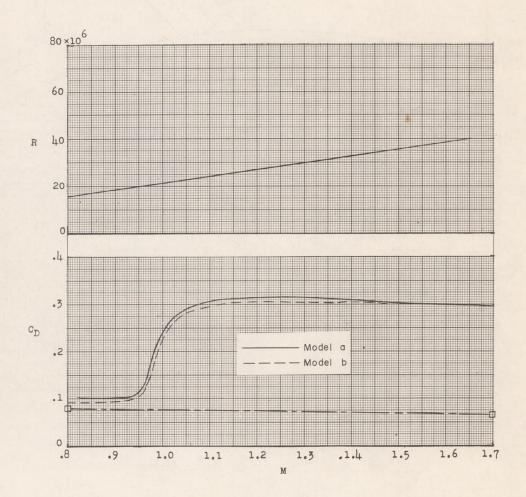
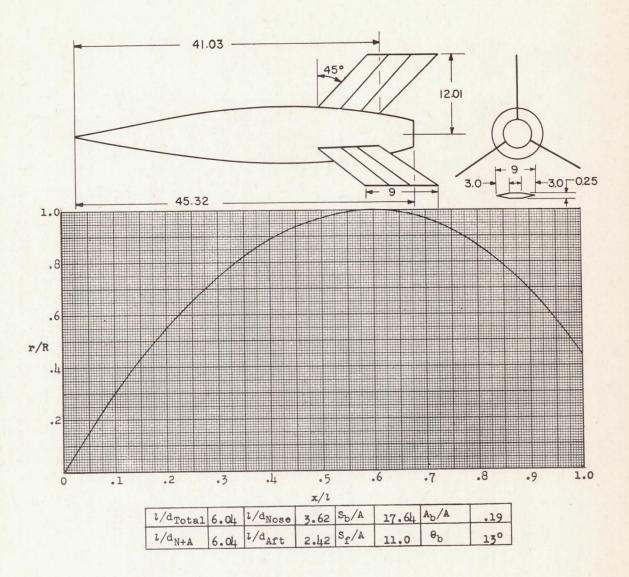


Figure 37. - Concluded.



Test: Rocket

Figure 38.

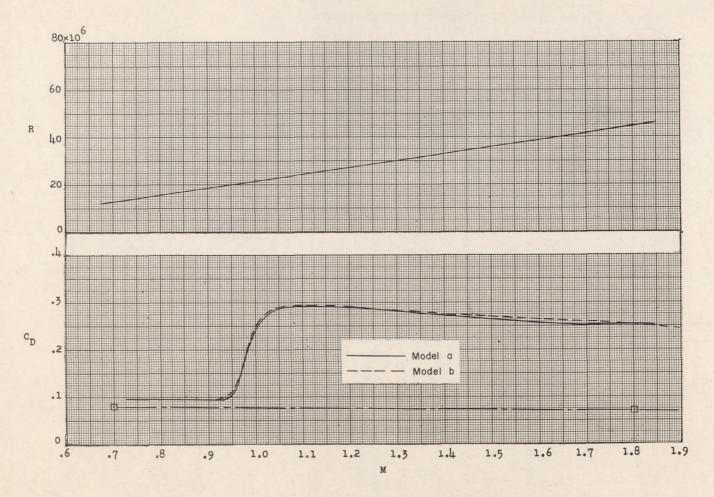


Figure 38. - Concluded.

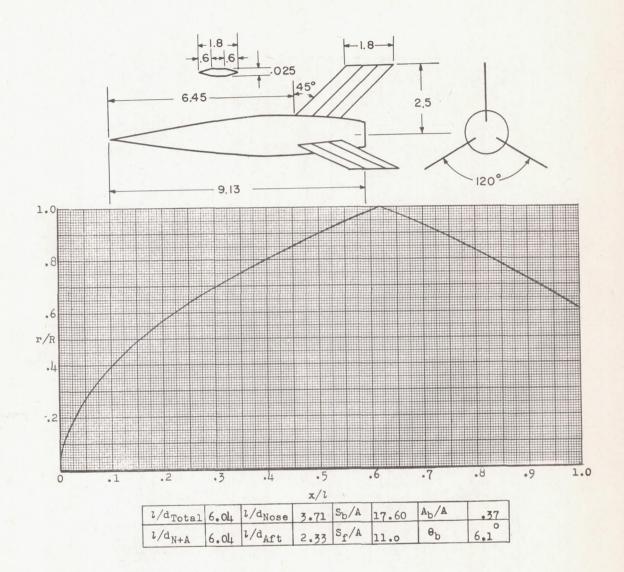


Figure 39.

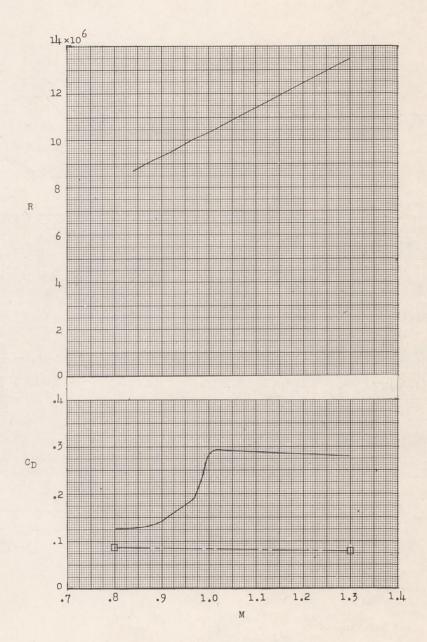


Figure 39.- Concluded.

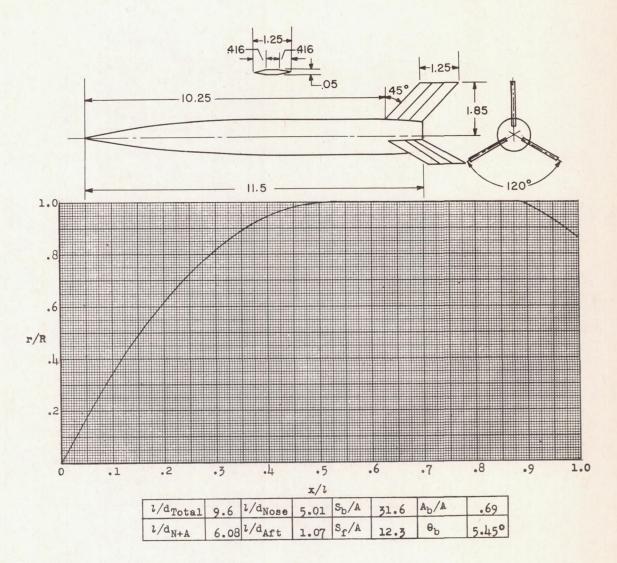


Figure 40.

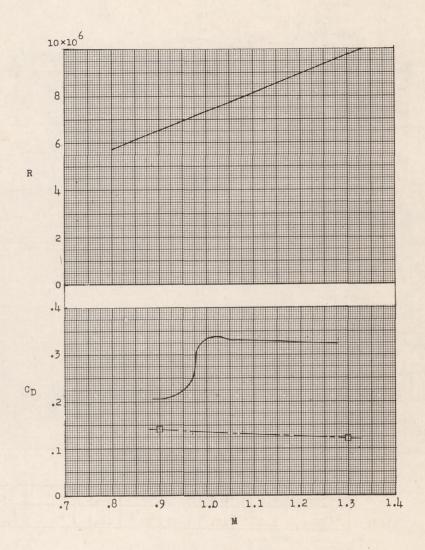
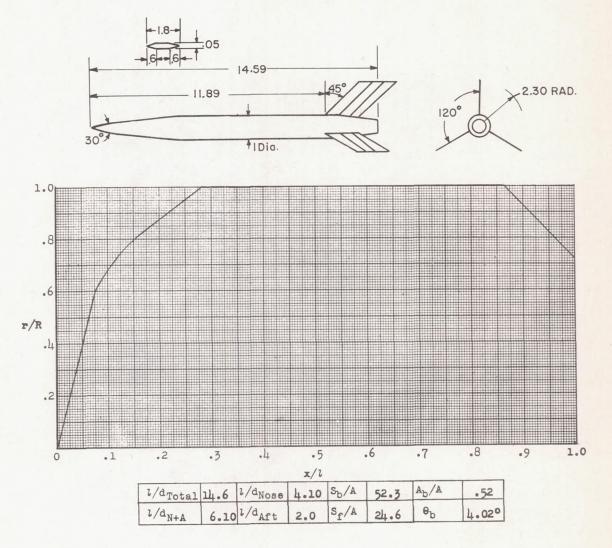


Figure 40.- Concluded.



Designation: 33 Test: Helium Gun

Remarks: This model 1/5 scale of model 34 (fig. 42); thus pressure drags of these two configurations should be the same. That they are not the same is obvious, however, if it is assumed that data of model 34 are in error in M about M = 0.05; then the subsonic levels and the early drag rises are compatible. This seems to be justified since the late drag rise of model 34 would be quite unusual if it really occurred. Model 36 (fig. 44) is similar to 34 and showed the more usual earlier rise. The continued increase in drag coefficient of model 33 above M = 1.1 is also peculiar and is probably in error.

Figure 41.

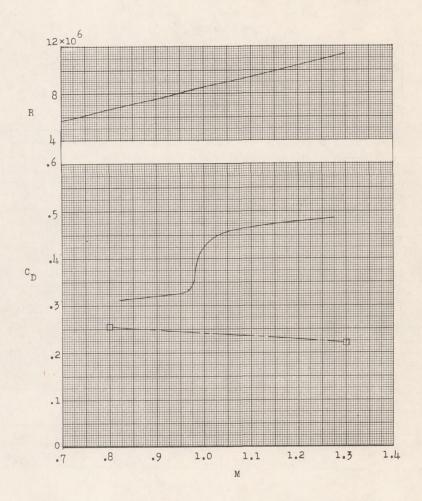
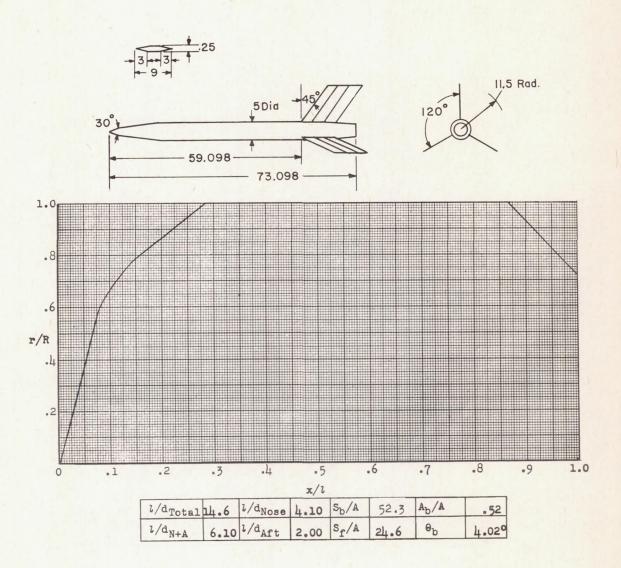


Figure 41. - Concluded.



Test: Rocket

Remarks: See figure 41.

Figure 42.

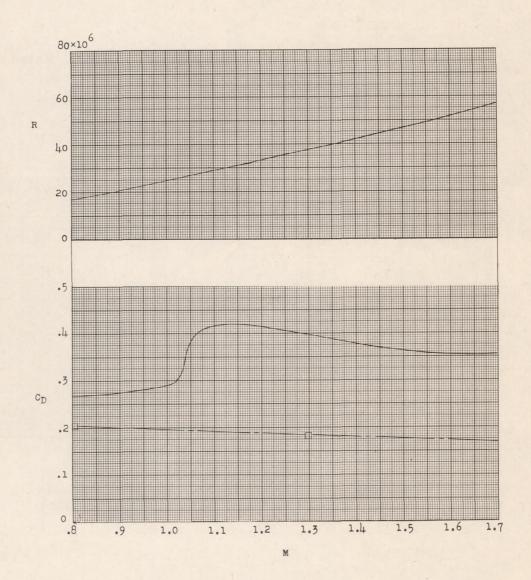


Figure 42. - Concluded.

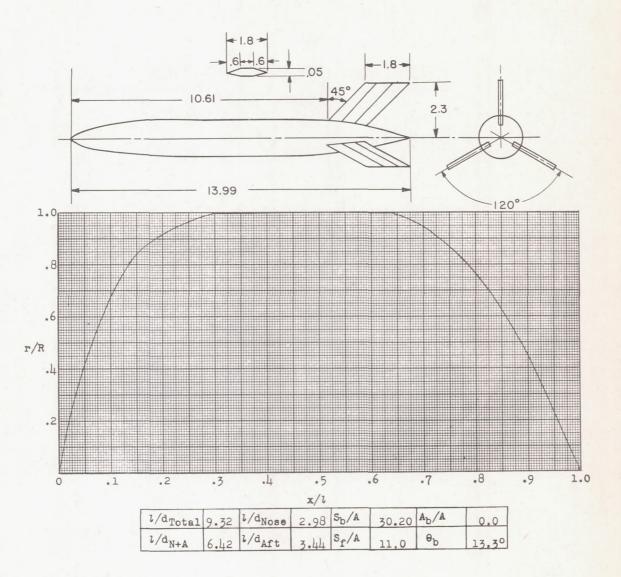


Figure 43.

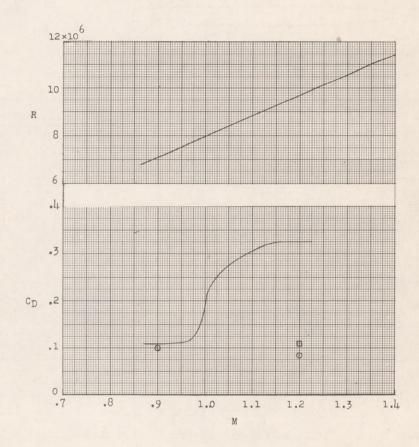
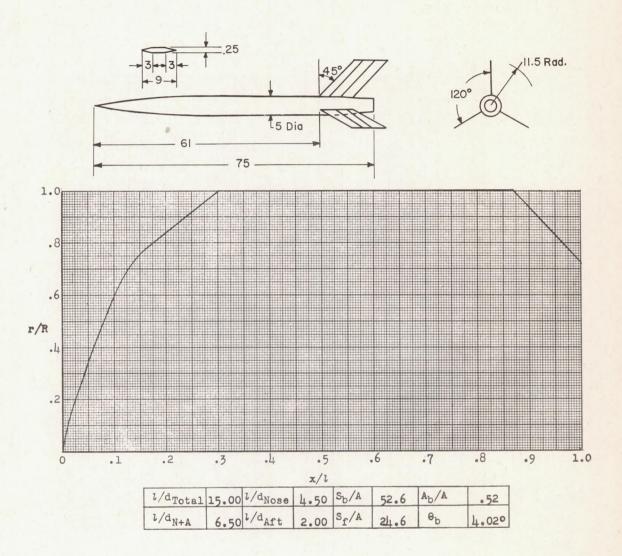


Figure 43.- Concluded.



Test: Rocket

Remarks: See figure 41.

Figure 44.

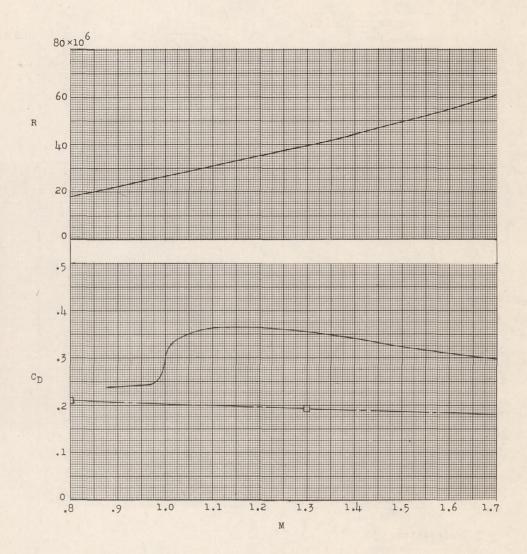
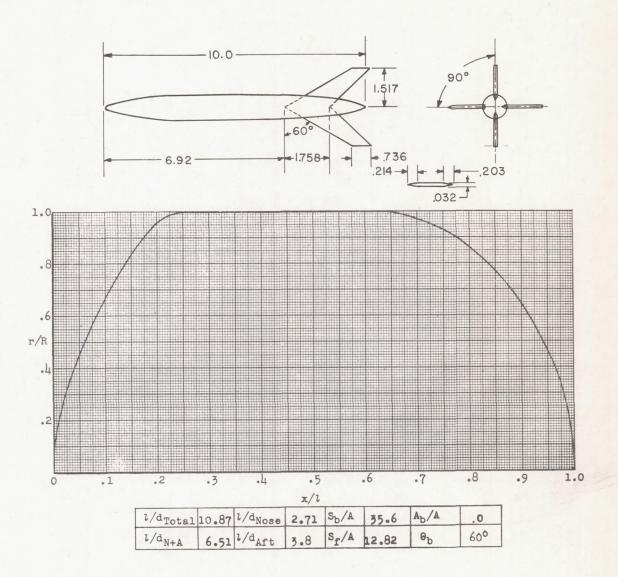


Figure 44.- Concluded.



Test: Helium Gun

Remarks: Nondimensional ordinates identical to configuration 10 (fig. 18).

Figure 45.

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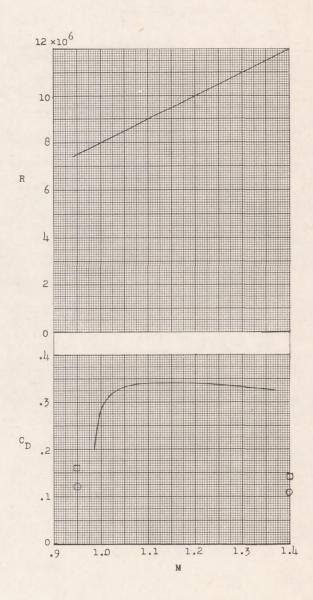
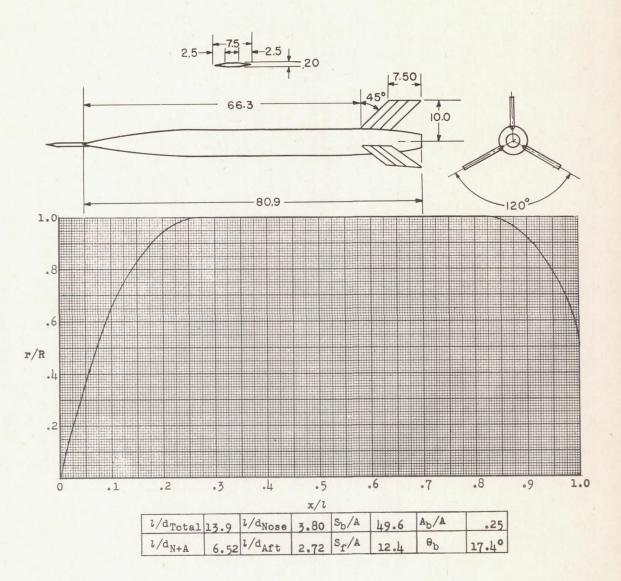


Figure 45.- Concluded.



Test: Rocket

Remarks: Spike can affect friction drag but is not likely to affect pressure drag.

Figure 46.

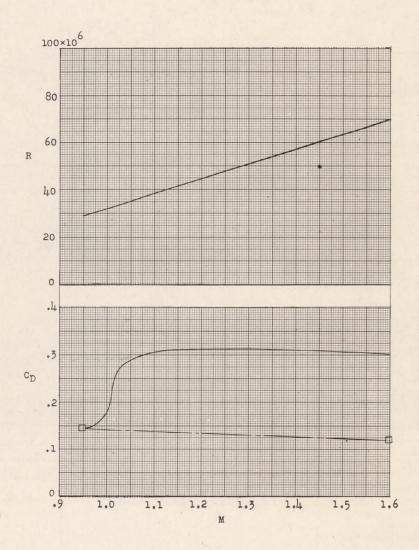


Figure 46.- Concluded.

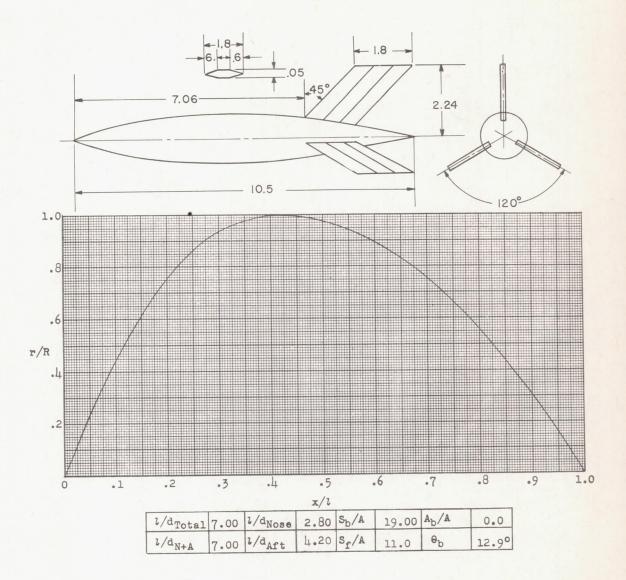


Figure 47.

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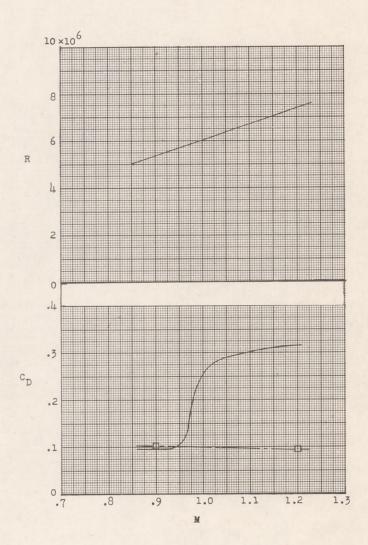
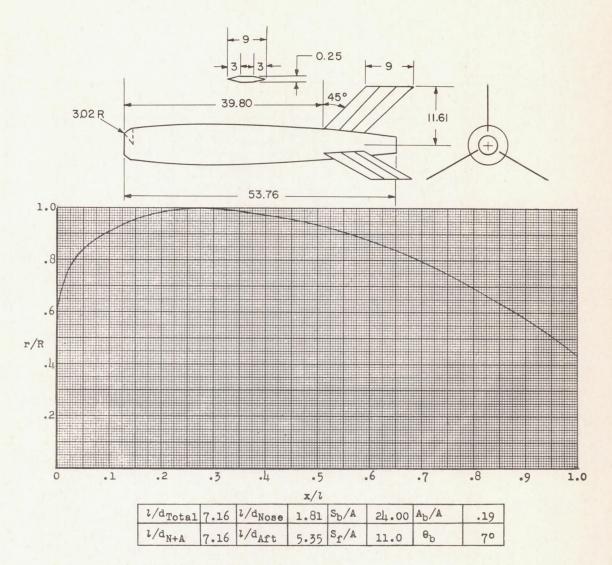


Figure 47.- Concluded.



Test: Rocket

Remarks: Flat nose having r/R = 0.57 flaired into parabolic segment by 3.02 radius; parabolic afterbody.

Figure 48.

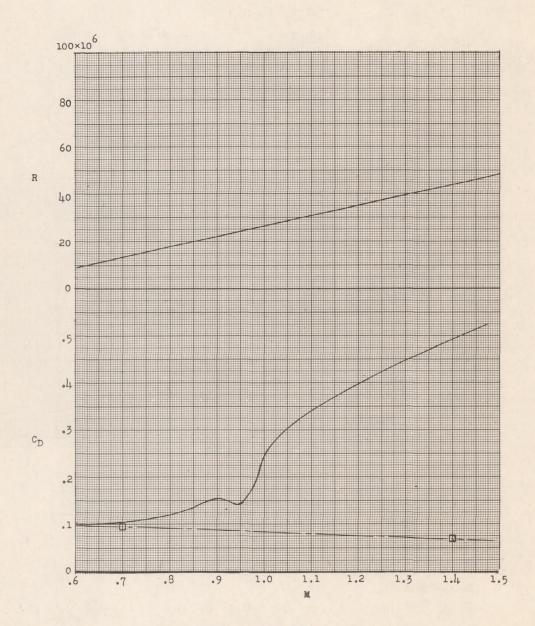
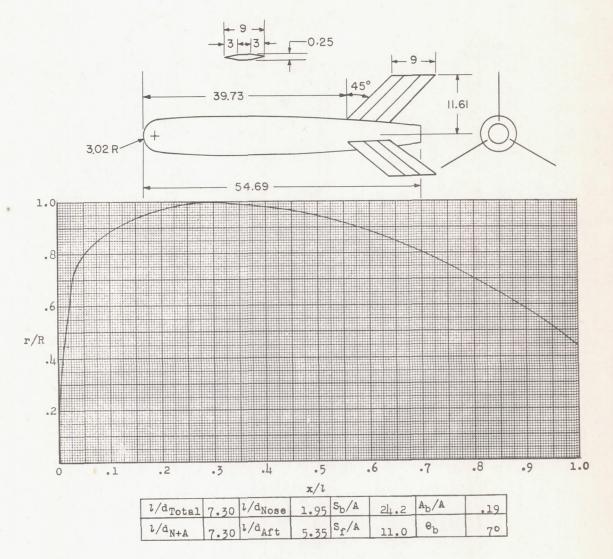


Figure 48. - Concluded.



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Test: Rocket

Remarks: Nose consists of hemispherical segment plus parabolic segment; parabolic afterbody.

Figure 49.

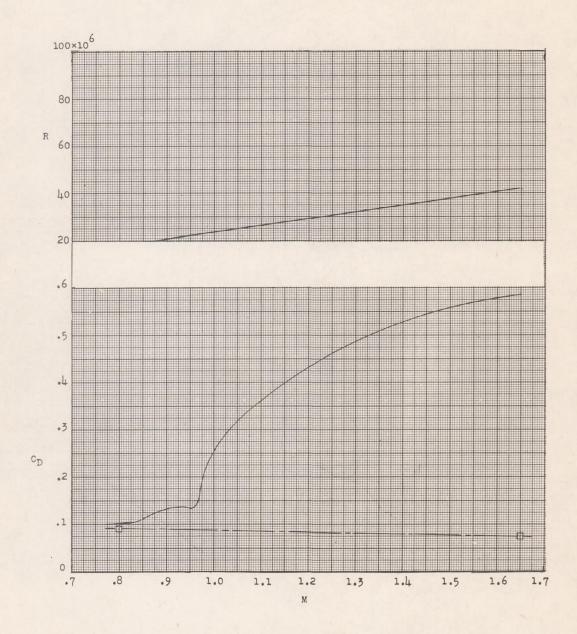


Figure 49.- Concluded.

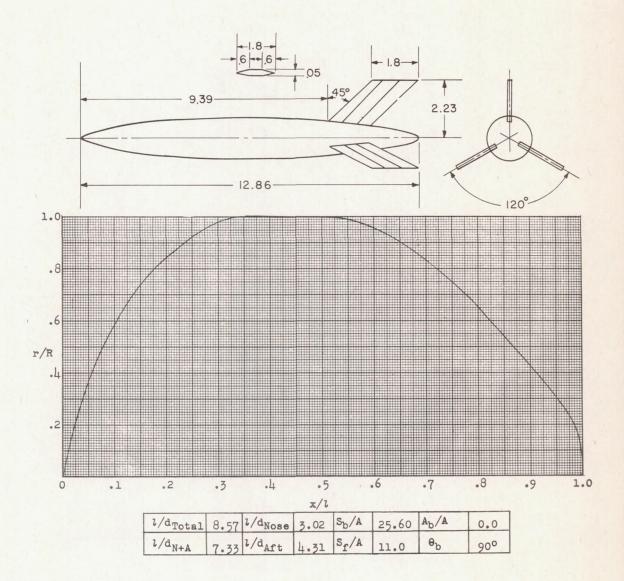


Figure 50.

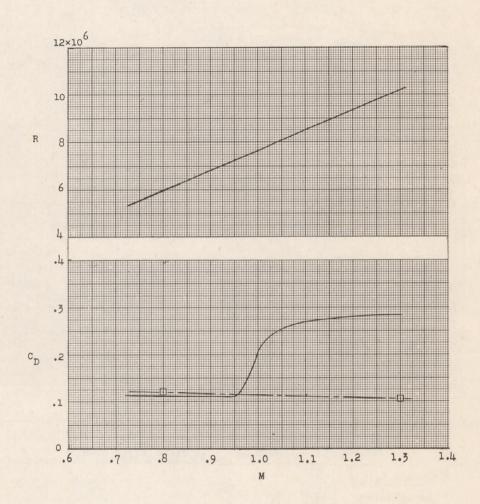
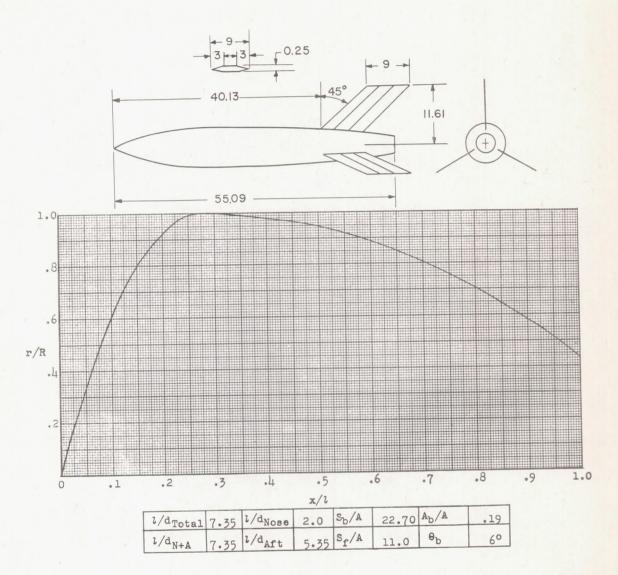


Figure 50. - Concluded.



Test: Rocket

Figure 51.

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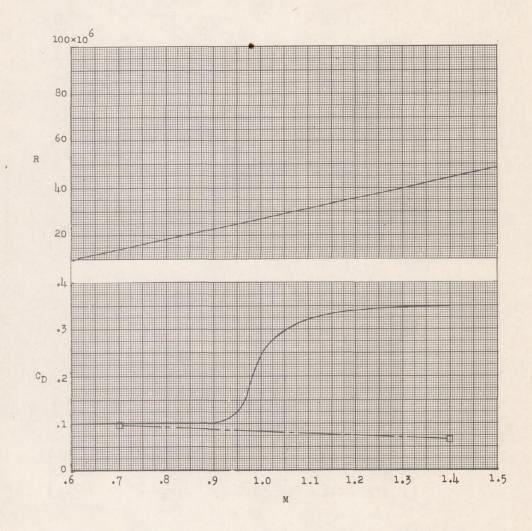


Figure 51. - Concluded.

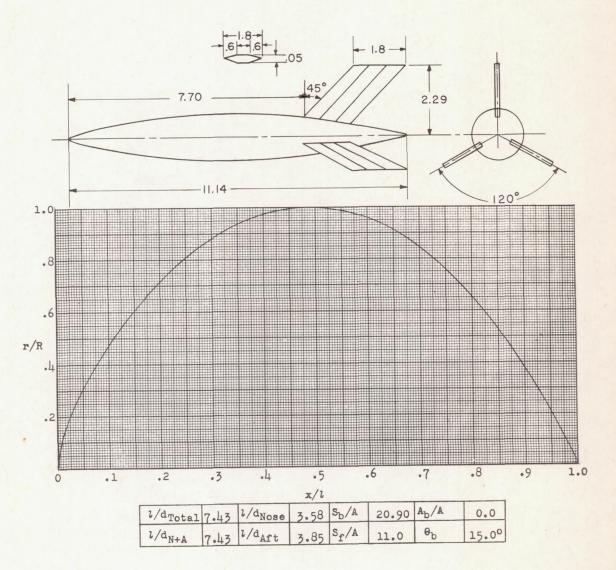


Figure 52.

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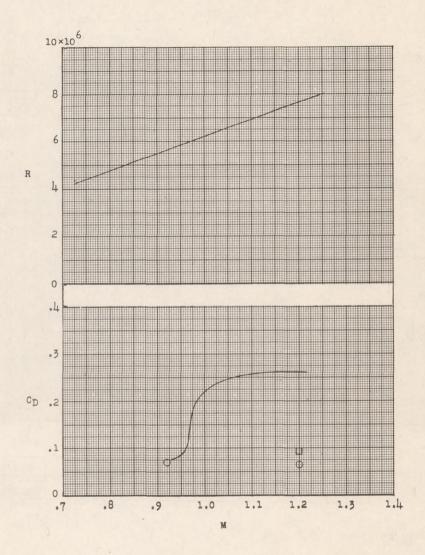
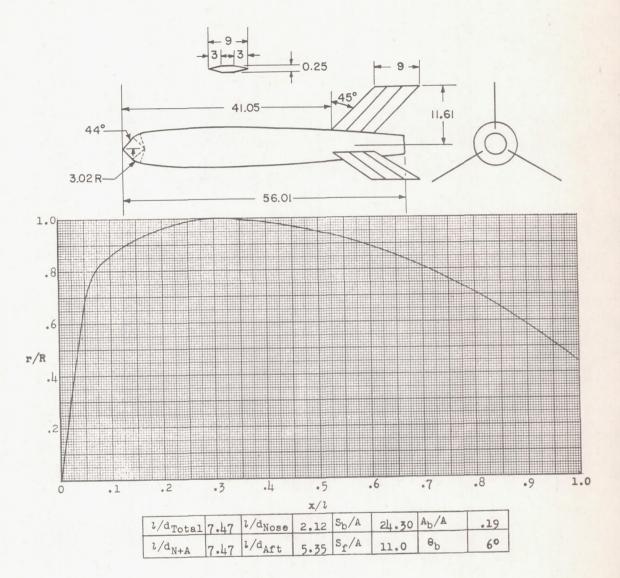


Figure 52. - Concluded.



Test: Rocket

Remarks: Conical nose with hemispherical and parabolic segments; parabolic afterbody.

Figure 53.

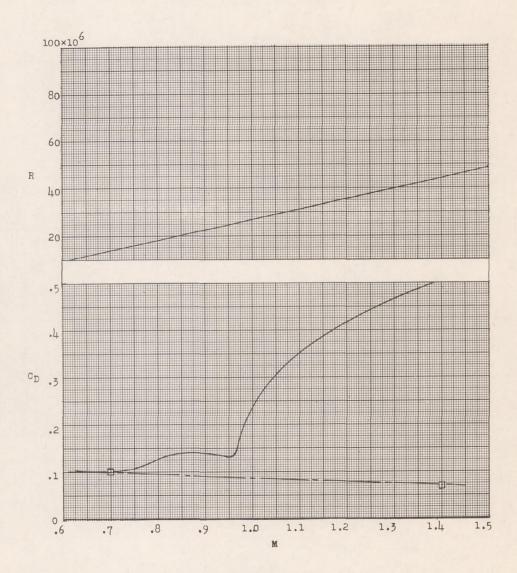
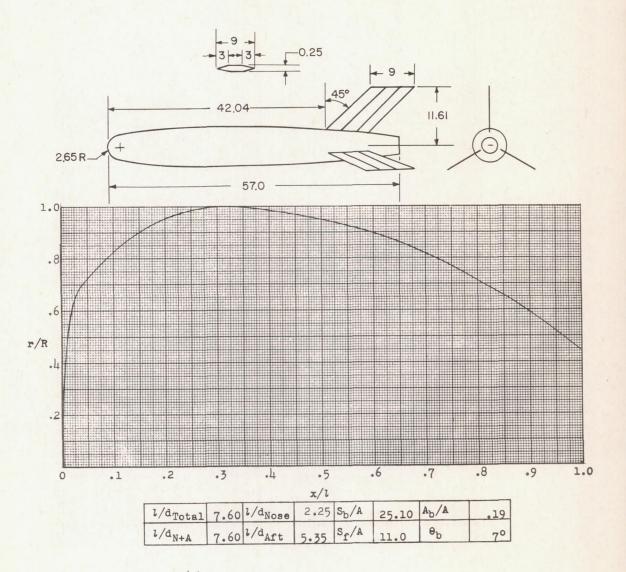


Figure 53.- Concluded.

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Designation: 46

Test: Rocket

Remarks: Nose with hemispherical and parabolic segments; parabolic afterbody.

Figure 54.

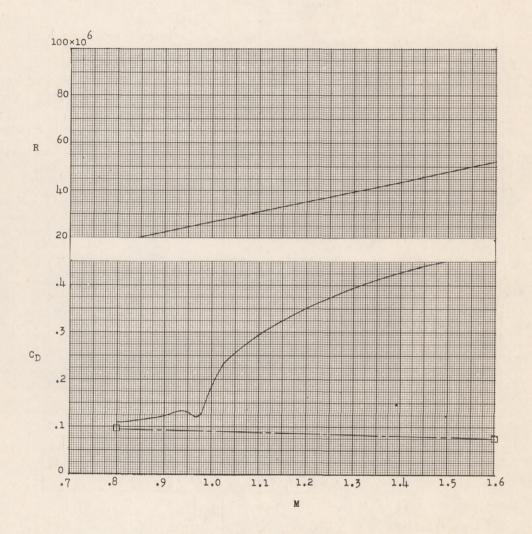
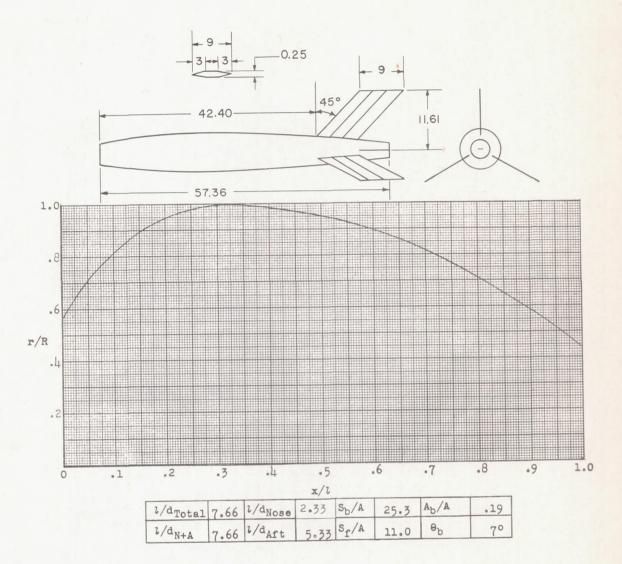


Figure 54. - Concluded.



Test: Rocket

Remarks: Nose consists of parabolic segment; parabolic afterbody.

Figure 55.

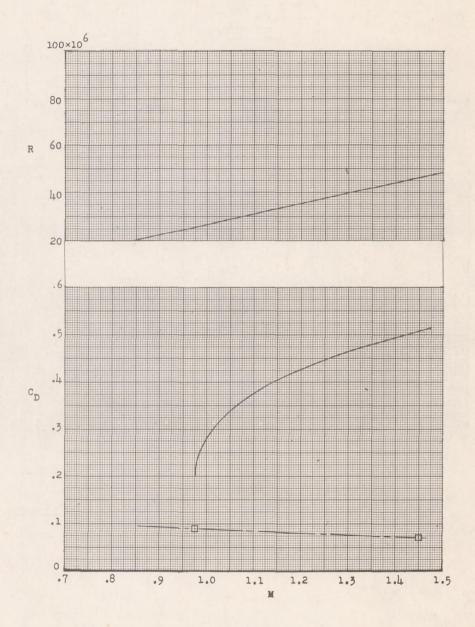
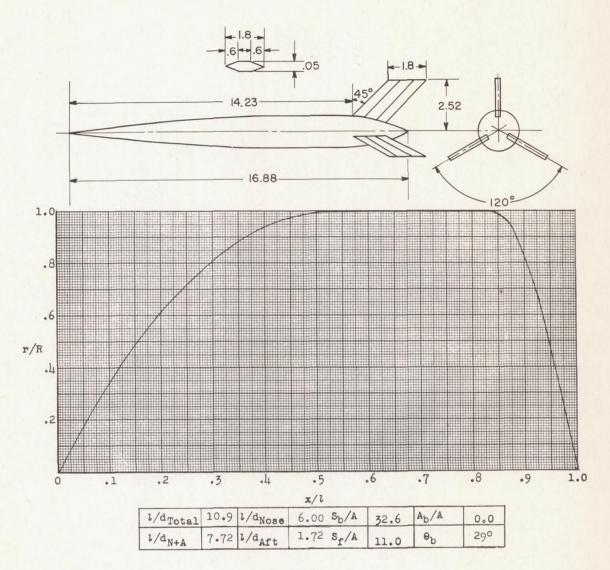


Figure 55. - Concluded.



Test: Helium Gun

Remarks: Body differs from configurations 49 and 50 (figs. 57 and 58) only in removal of Mach 1 area distribution of fins from afterbodies of these models.

Figure 56.

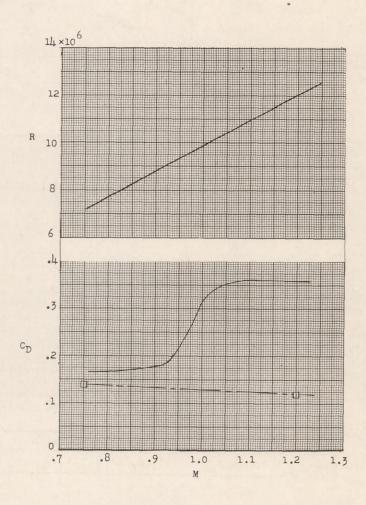
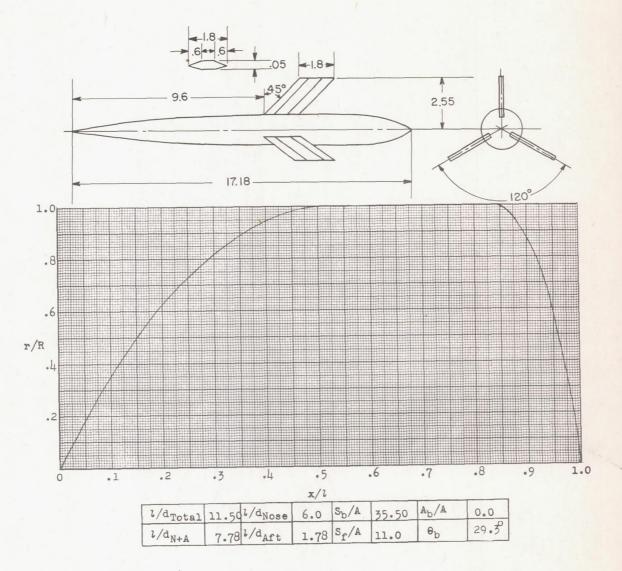


Figure 56.- Concluded.



Test: Helium Gun

Remarks: Parabolic nose and afterbody; body identical to configuration 50. (See note for configuration 48 (fig. 56).)

Figure 57.

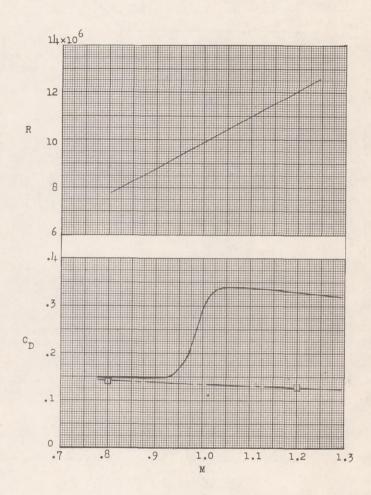
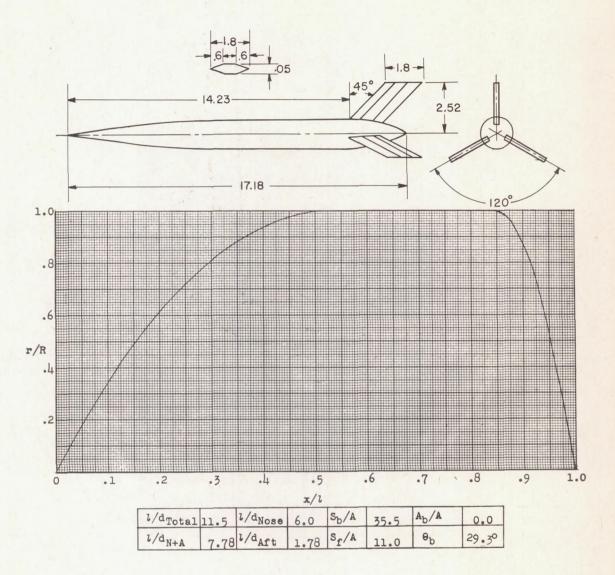


Figure 57. - Concluded.



Test: Helium Gun

Remarks: Parabolic nose and afterbody; body identical to configuration 49. (See note for configuration 48 (fig. 56).)

Figure 58.

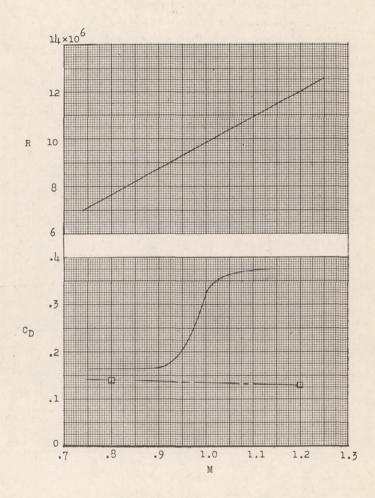


Figure 58. - Concluded.

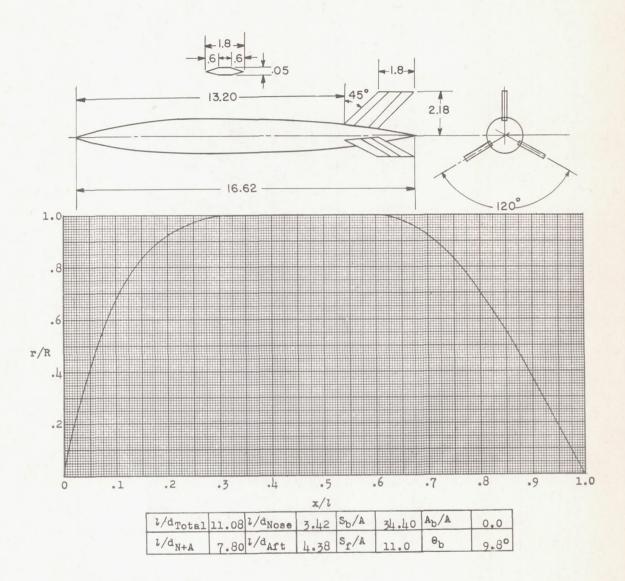


Figure 59.

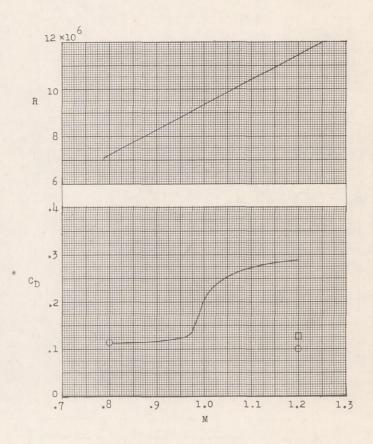
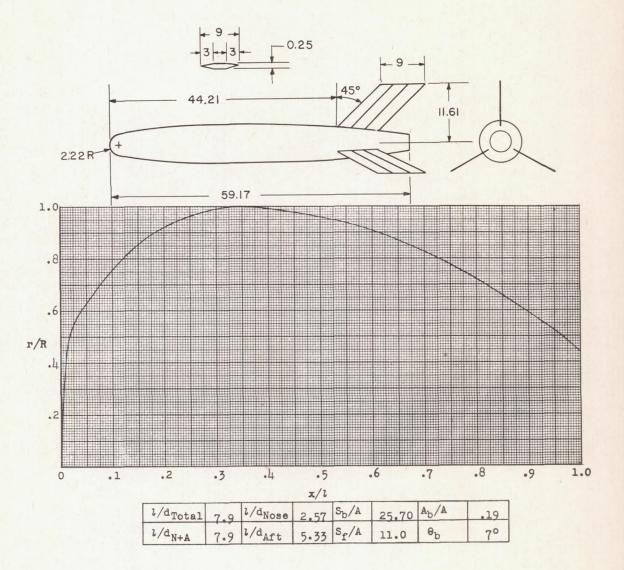


Figure 59. - Concluded.

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Designation: 52

Test: Rocket

Remarks: Nose consists of hemispherical and parabolic segments; parabolic afterbody.

Figure 60.

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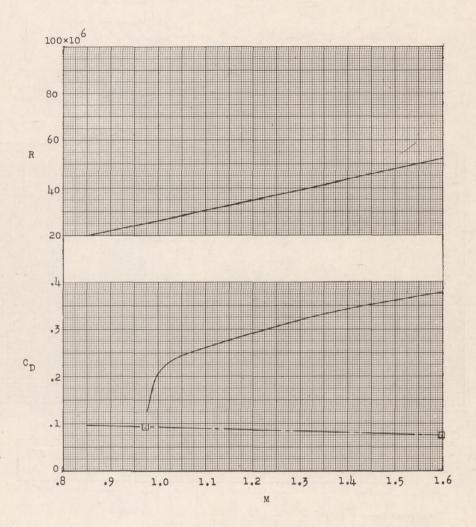


Figure 60.- Concluded.

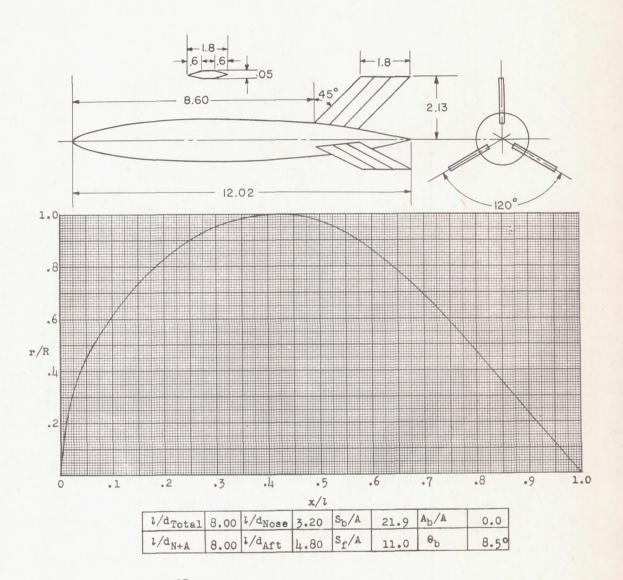


Figure 61.

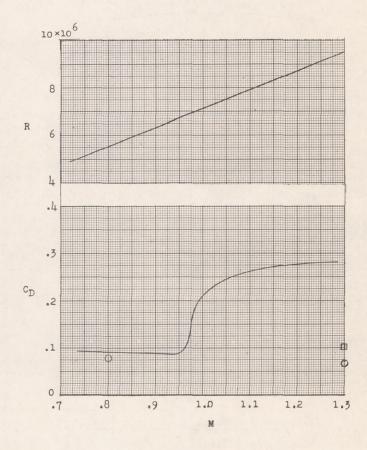


Figure 61. - Concluded.

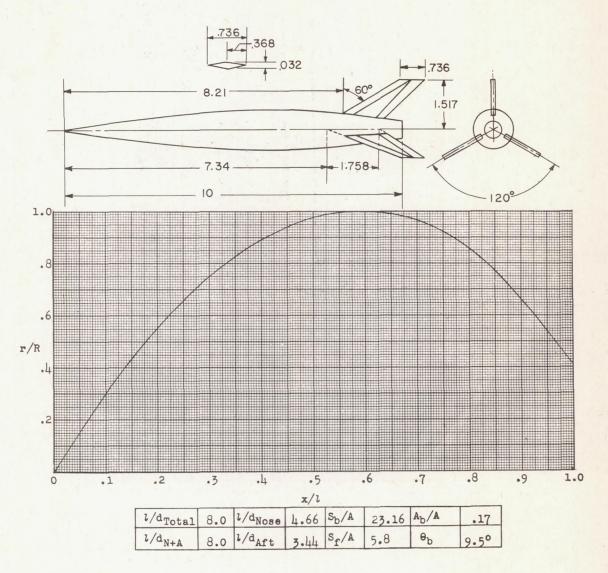


Figure 62.

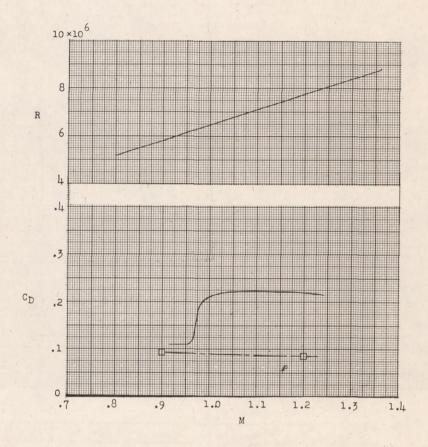
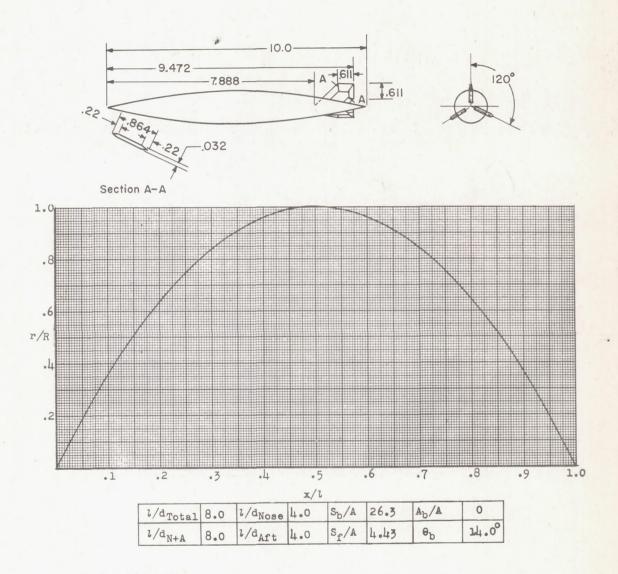


Figure 62.- Concluded.



Designation: 55

Test: Helium Gun

Figure 63.

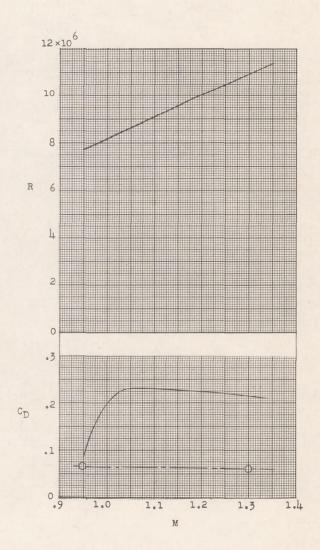
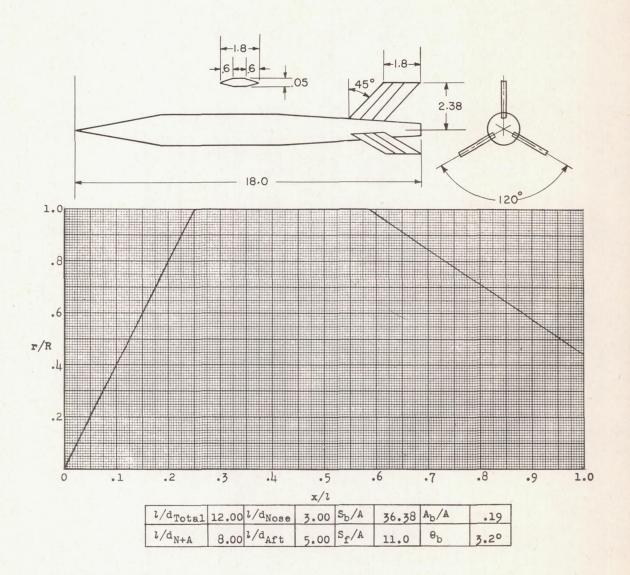


Figure 63.- Concluded.



Test: Helium Gun

Remarks: Conical nose and afterbody.

Figure 64.

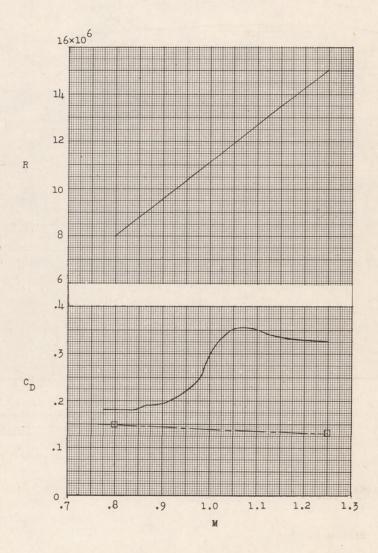
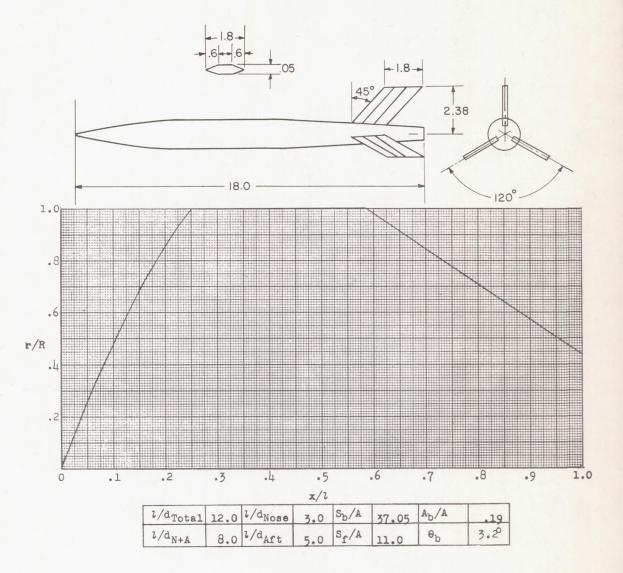


Figure 64.- Concluded.



Test: Helium Gun

Remarks: Nose,
$$r' = \frac{2x' - \frac{1}{2}(x')^2}{1\frac{1}{2}}$$
; conical afterbody.

Figure 65.

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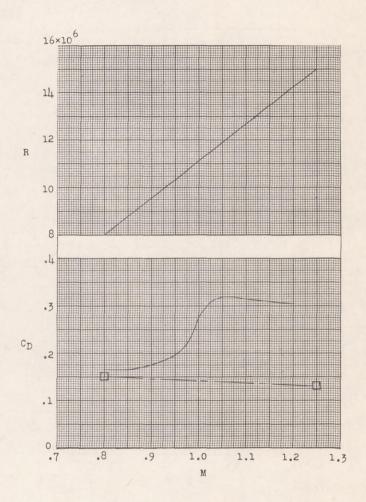
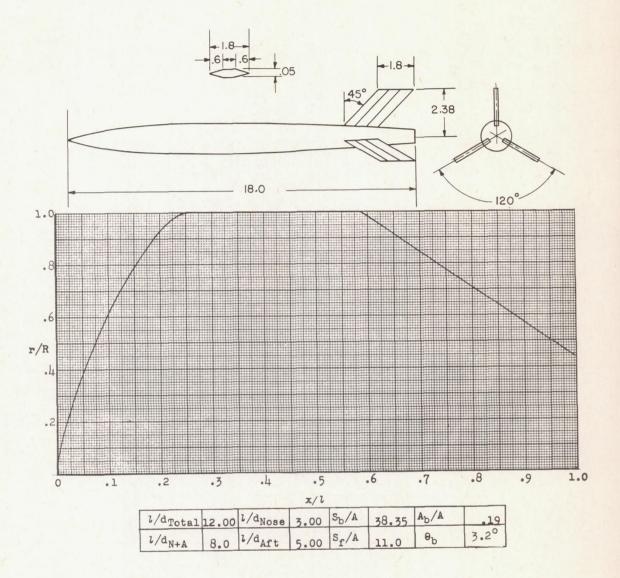


Figure 65.- Concluded.



Test: Helium Gun

Remarks: Nose, Von Karmán, $r' = \frac{1}{\sqrt{\pi}} \sqrt{\phi - 1/2 \sin^2\!\phi}$ where $\phi = \cos^{-1}(1 - 2x')$; conical afterbody.

Figure 66.

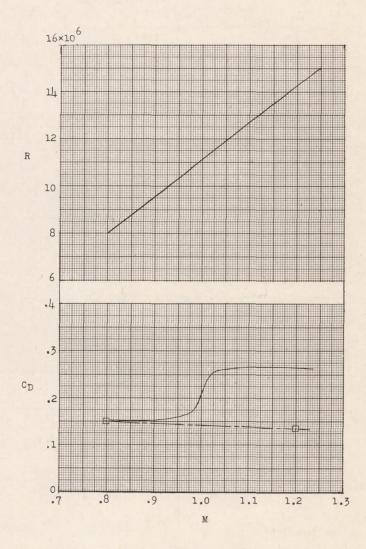
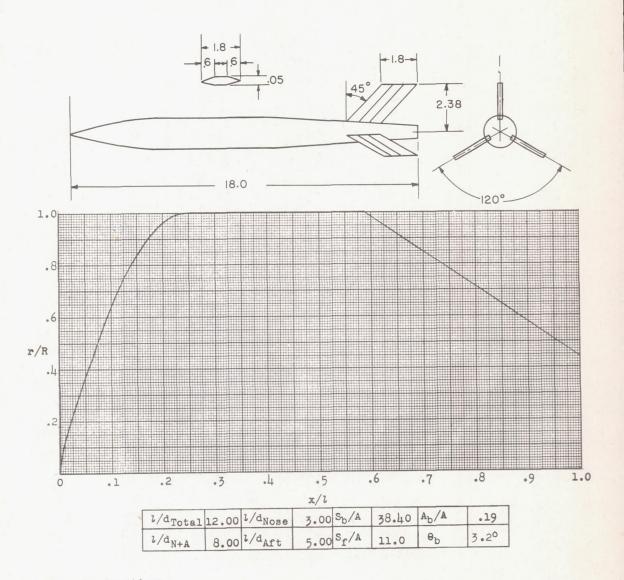


Figure 66.- Concluded.



Test: Helium Gun

Remarks: Parabolic nose; conical afterbody.

Figure 67.

141

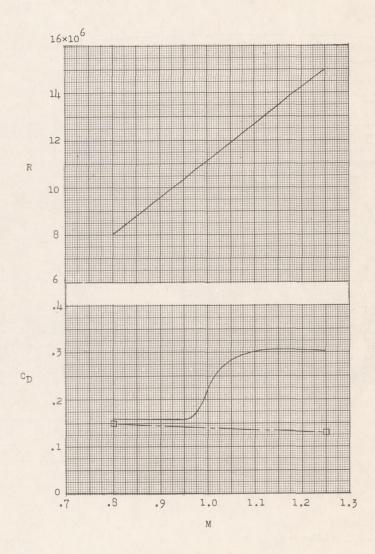
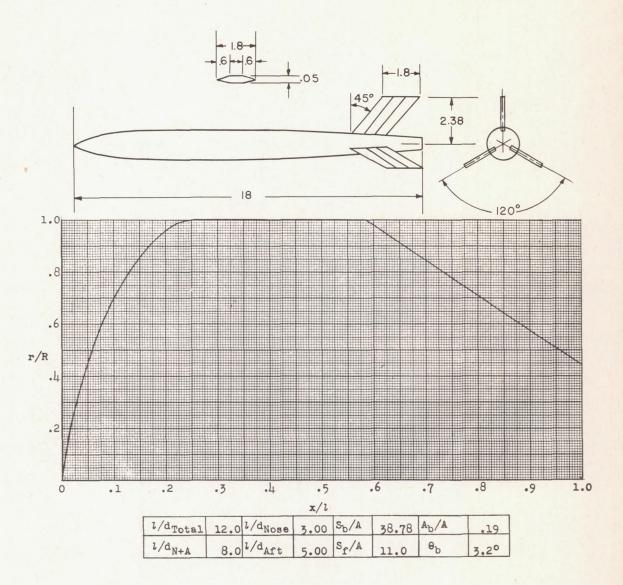


Figure 67.- Concluded.



Remarks: Nose, L-V Haack,
$$r' = \frac{1}{\sqrt{\pi}} \sqrt{\phi} - 1/2 \sin^2\!\phi + 1/3 \sin^3\!\phi$$
 where $\phi = \cos^{-1}(1 - 2X')$.

Figure 68.

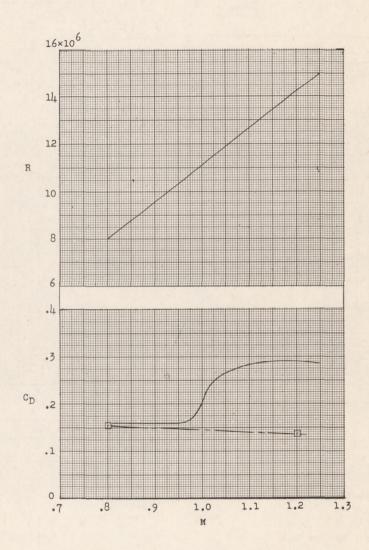
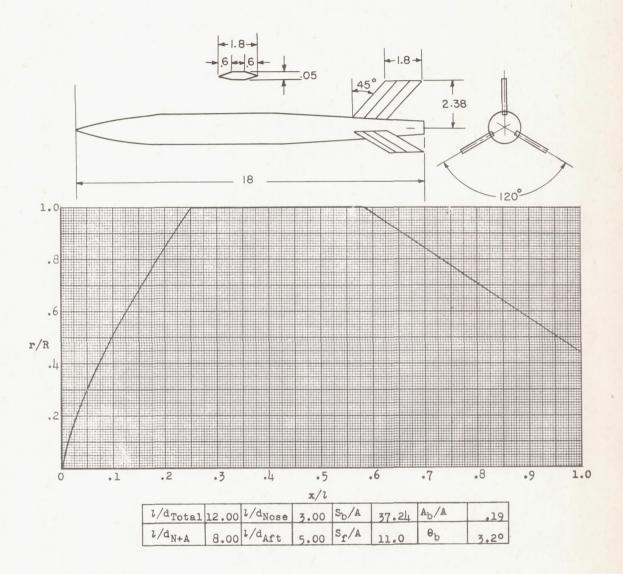


Figure 68. - Concluded.



Test: Helium Gun

Remarks: Nose, $r' = x^{13/4}$.

Figure 69.

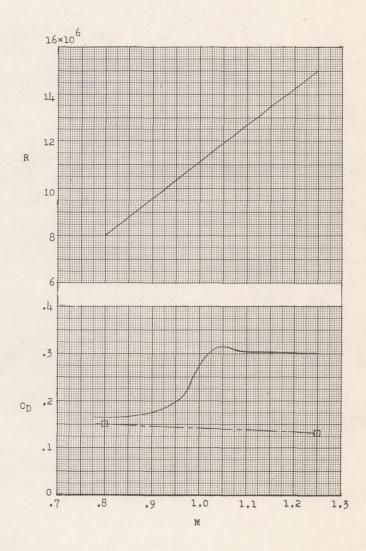
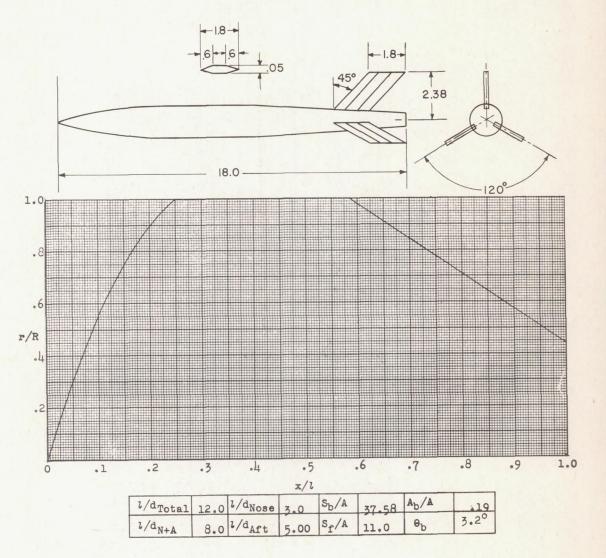


Figure 69.- Concluded.



Remarks: Nose,
$$r' = \frac{2x' - \frac{3}{4}x'^2}{1.25}$$
.

Figure 70.

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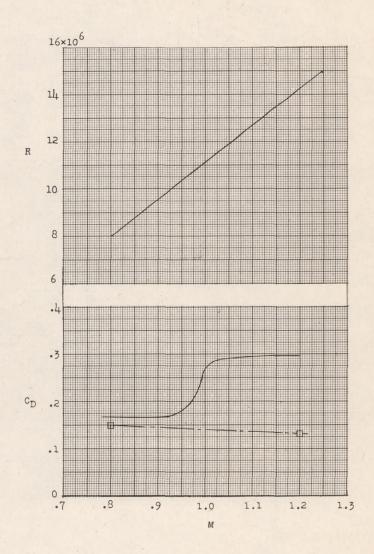
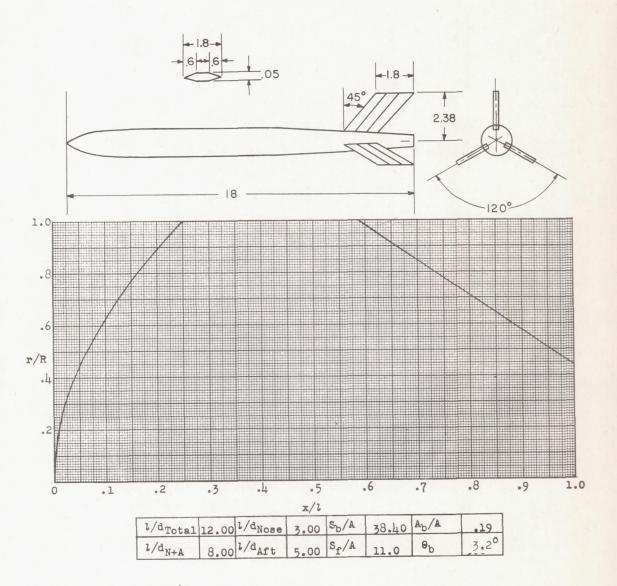


Figure 70. - Concluded.



Test: Helium Gun

Remarks: Nose, $r' = x' \frac{1}{2}$; conical afterbody.

Figure 71.

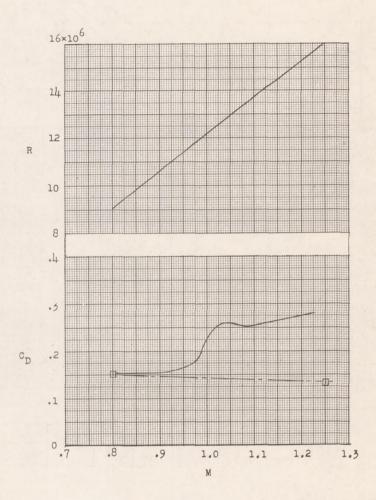
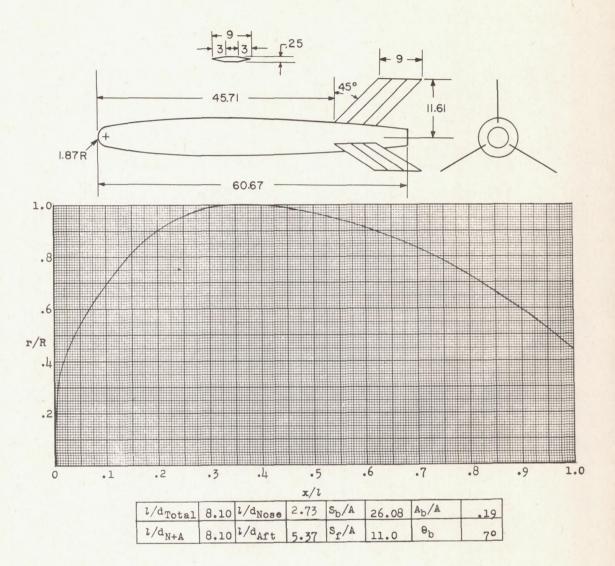


Figure 71. - Concluded.



Test: Rocket

Remarks: Nose consists of hemispherical and parabolic segments; parabolic afterbolic.

Figure 72.

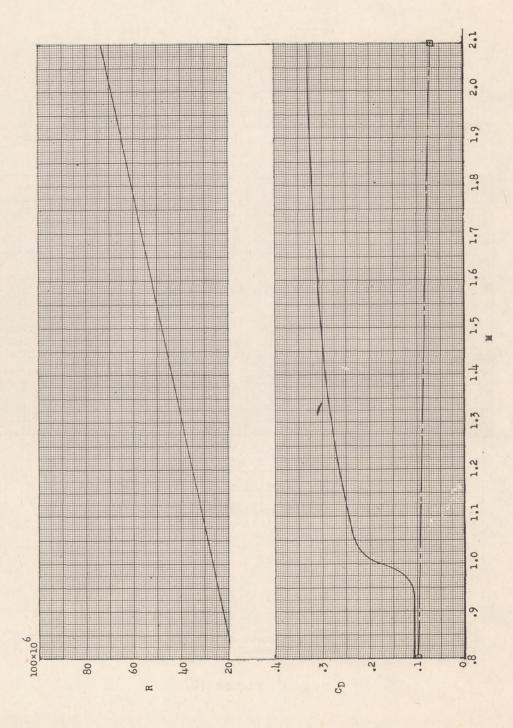


Figure 72. - Concluded.

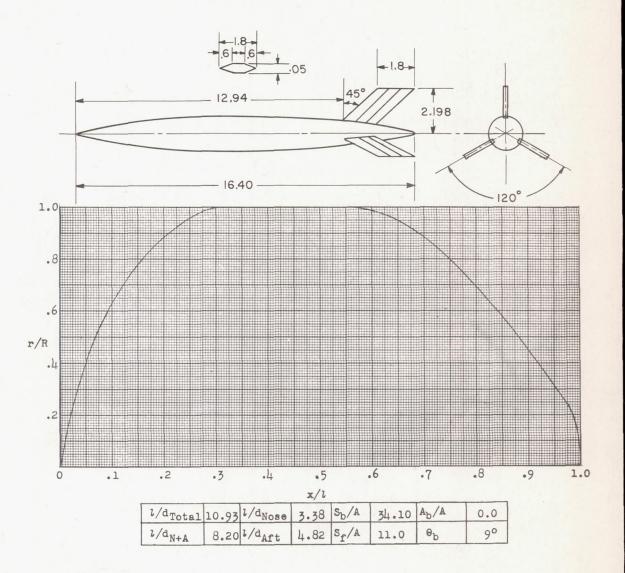


Figure 73.

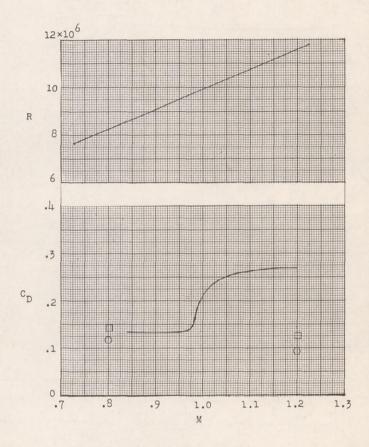
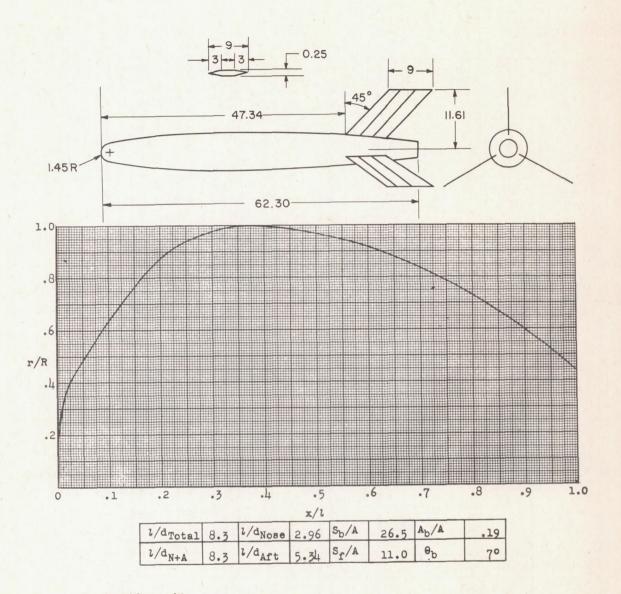


Figure 73.- Concluded.



Test: Rocket

Remarks: Nose consists of hemispherical and parabolic segments; parabolic afterbody.

Figure 74.

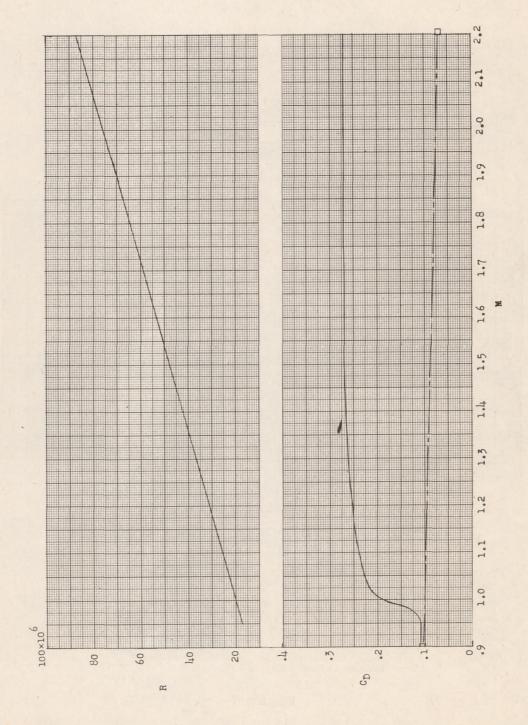


Figure 74.- Concluded.

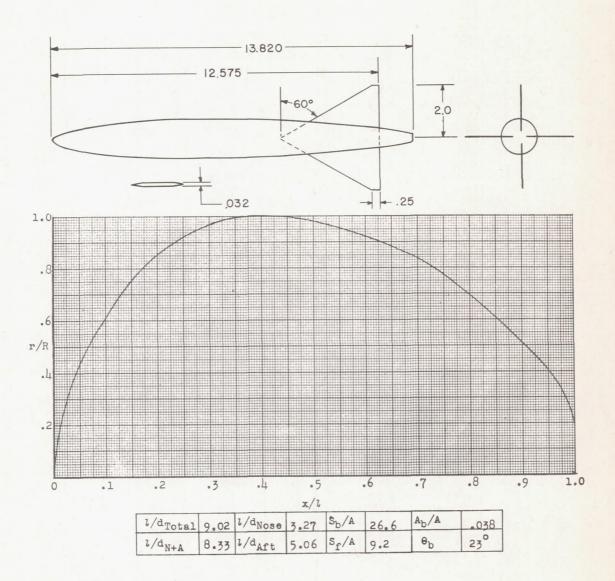


Figure 75.

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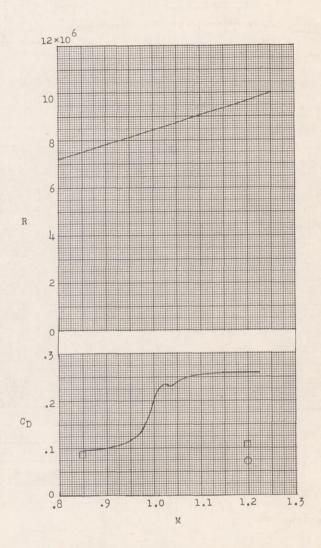
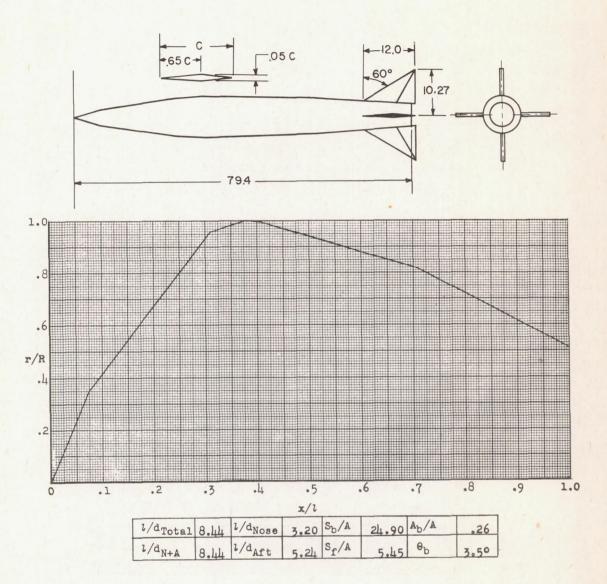


Figure 75. - Concluded.



Test: Rocket

Remarks: All conical sections.

Figure 76.

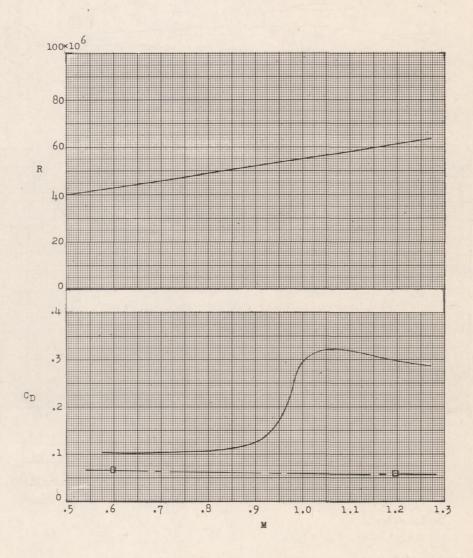
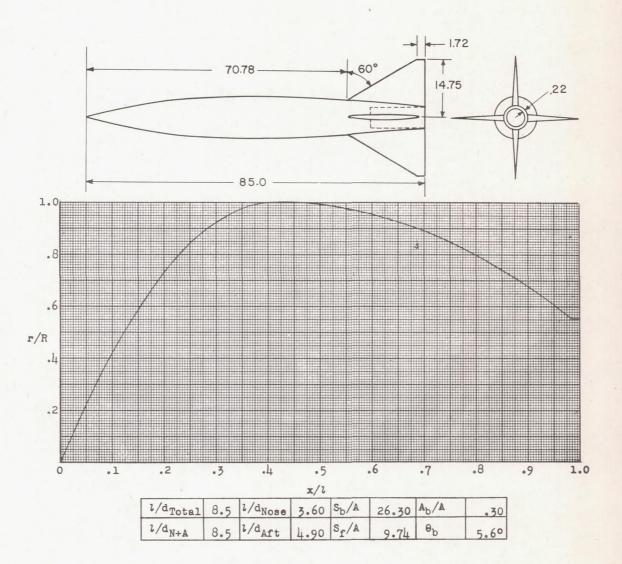


Figure 76.- Concluded.



Designation: 69

Test: Rocket

Figure 77.

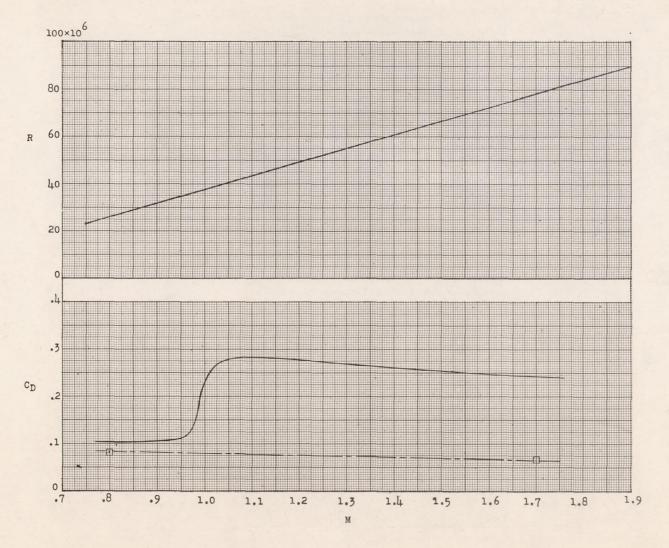
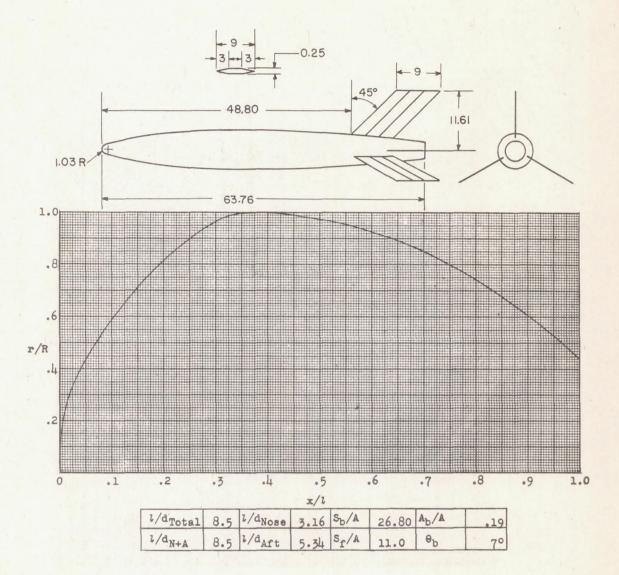


Figure 77.- Concluded.



Test: Rocket

Remarks: Nose consists of hemispherical and parabolic segments; parabolic afterbody.

Figure 78.

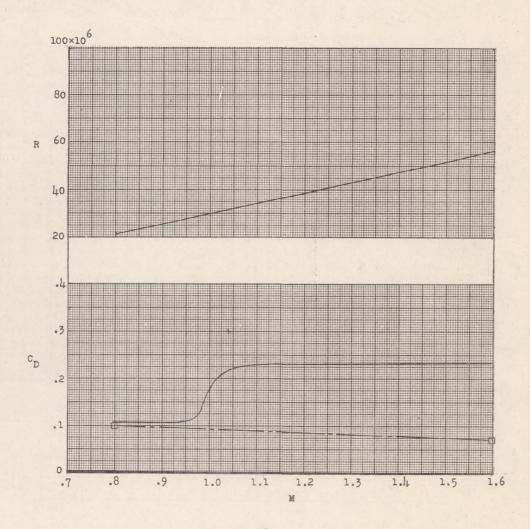
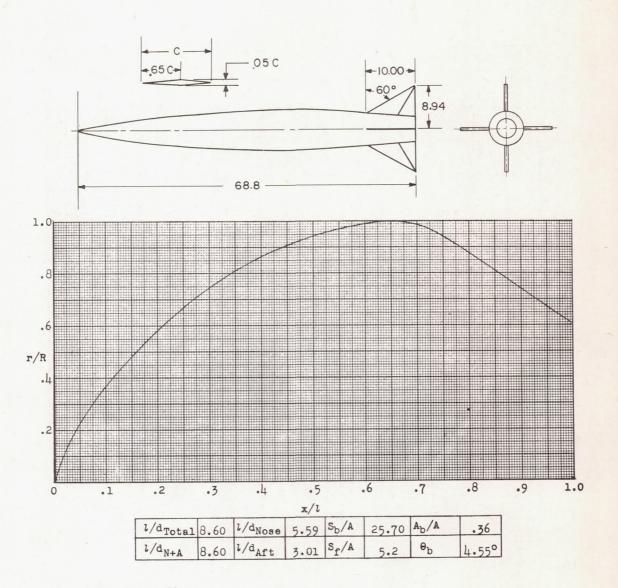


Figure 78. - Concluded.



Test: Rocket

Figure 79.

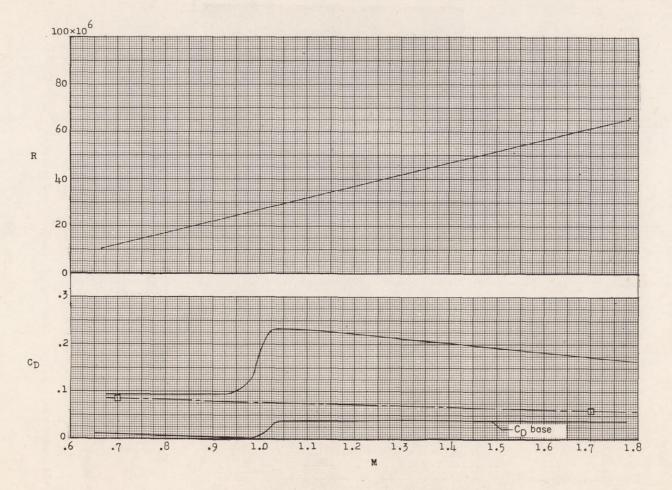
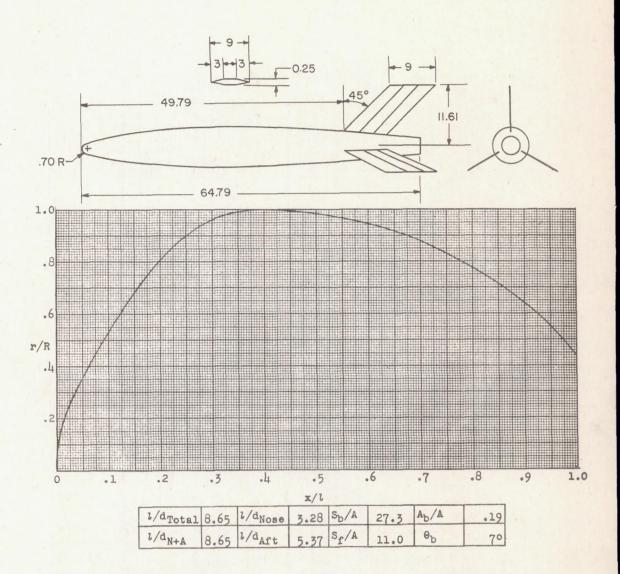


Figure 79.- Concluded.



Test: Rocket

Remarks: Nose consists of hemispherical and parabolic segments; parabolic afterbody.

Figure 80.

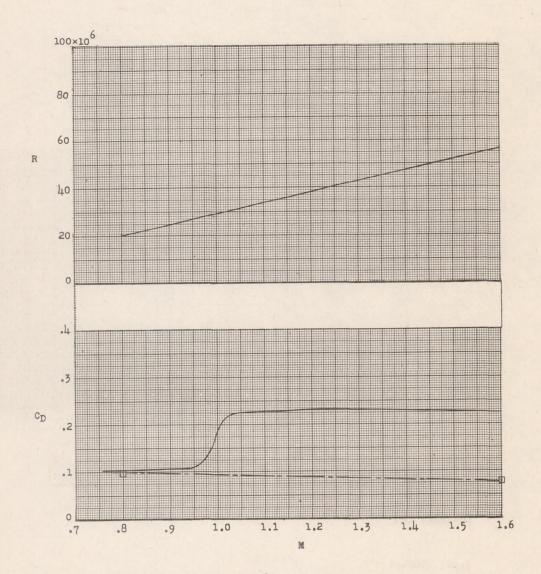


Figure 80.- Concluded.

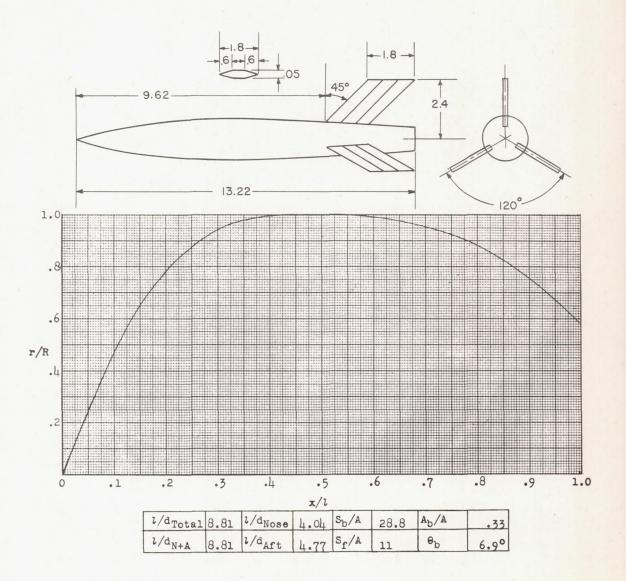


Figure 81.

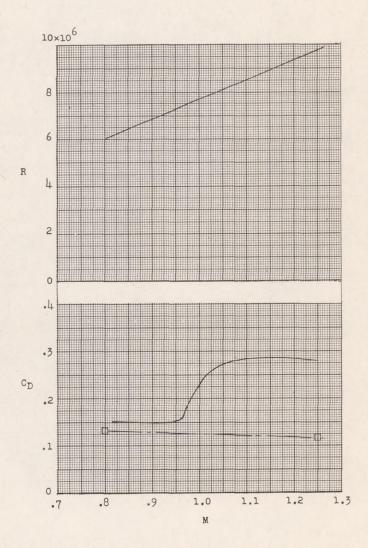
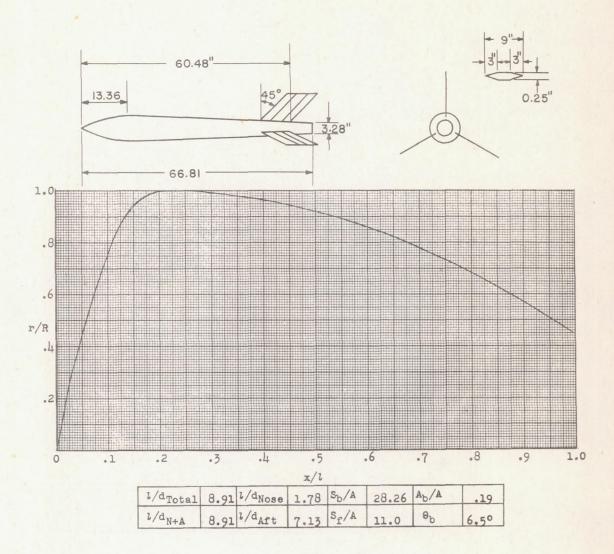


Figure 81. - Concluded.



Test: Rocket

Remarks: Parabolic nose and afterbody.

Figure 82.

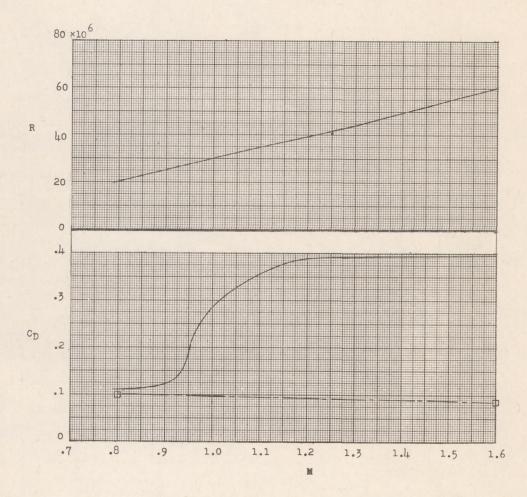
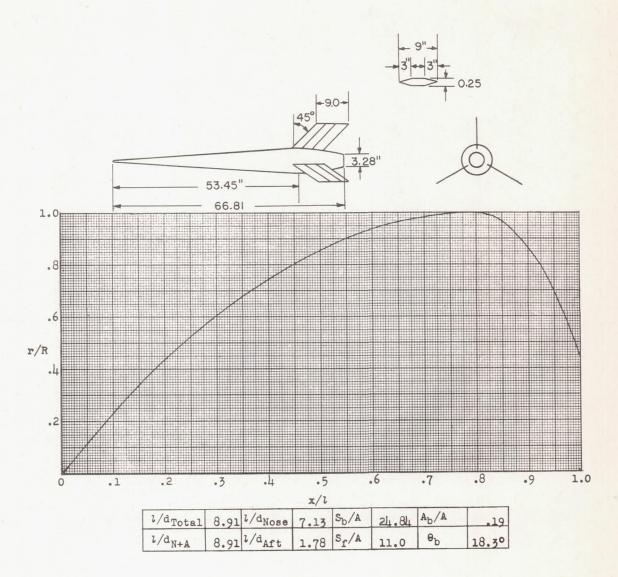


Figure 82.- Concluded.



Test: Rocket

Remarks: Parabolic nose and afterbody.

Figure 83.

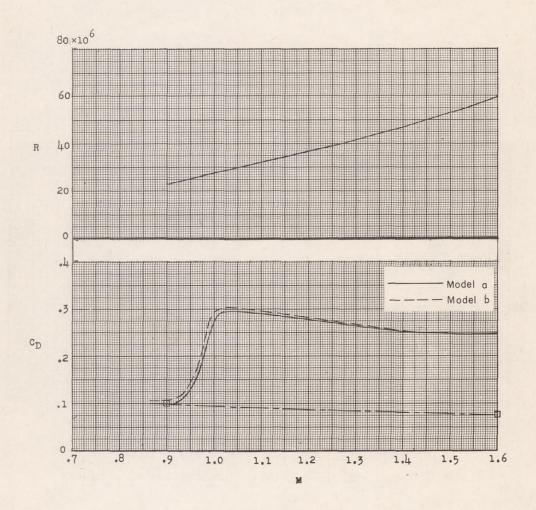
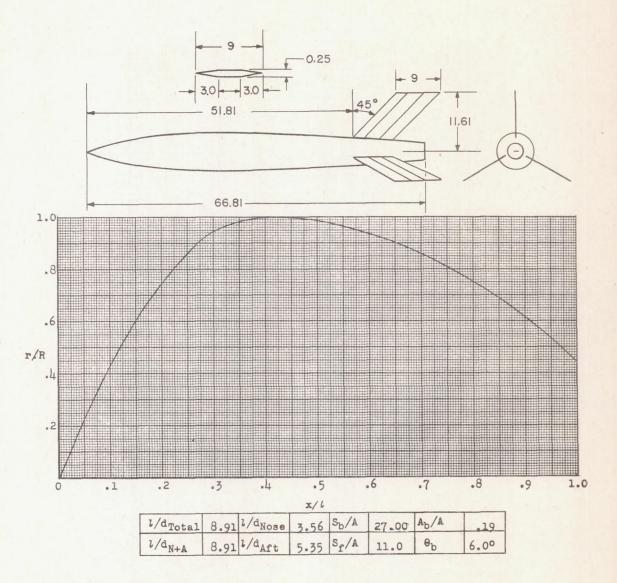


Figure 83. - Concluded.

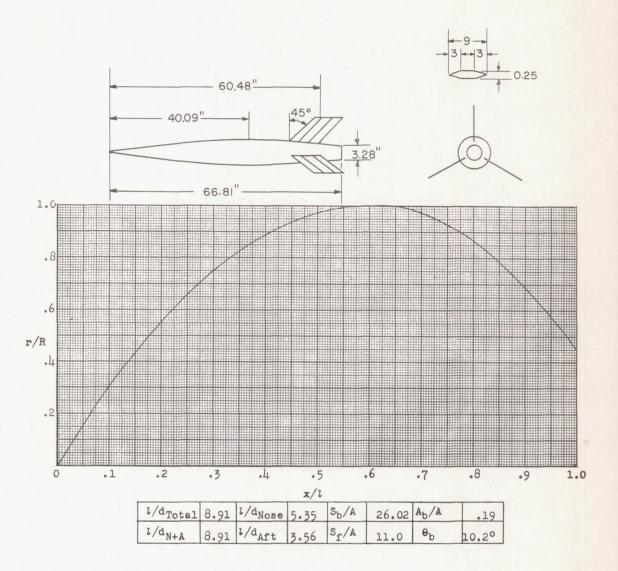


Test: Rocket

Remarks: Parabolic nose and afterbody; waviness of coefficient of low Mach number models is probably due to afterburning of their sustainer rockets.

Figure 84.

Figure 84. - Concluded.



Test: Rocket

Remarks: Parabolic nose and afterbody.

Figure 85.

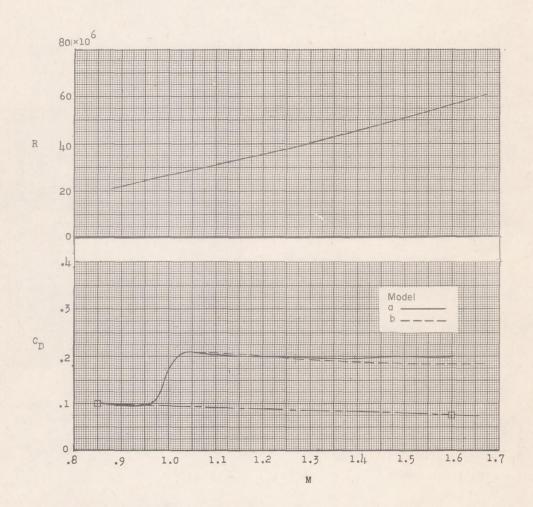
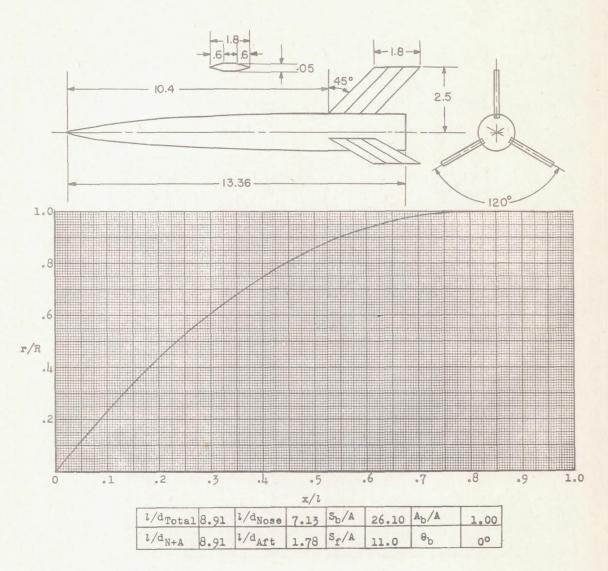


Figure 85. - Concluded.



Test: Helium Gun

Remarks: Parabolic nose.

Figure 86.



Figure 86. - Concluded.

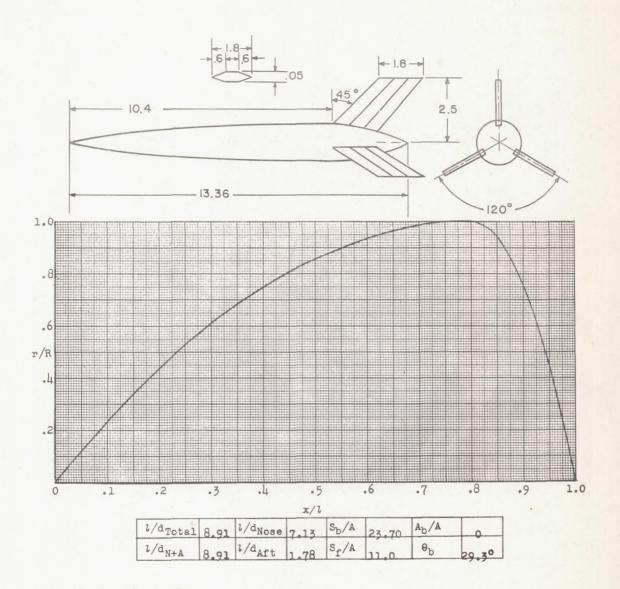


Figure 87.

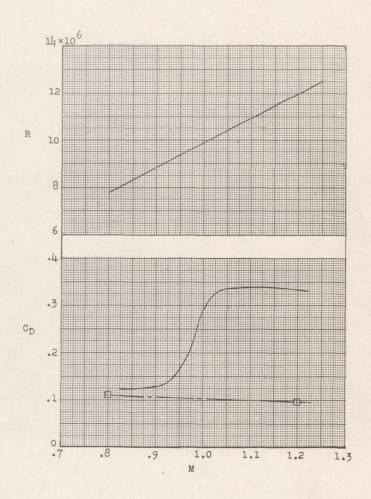
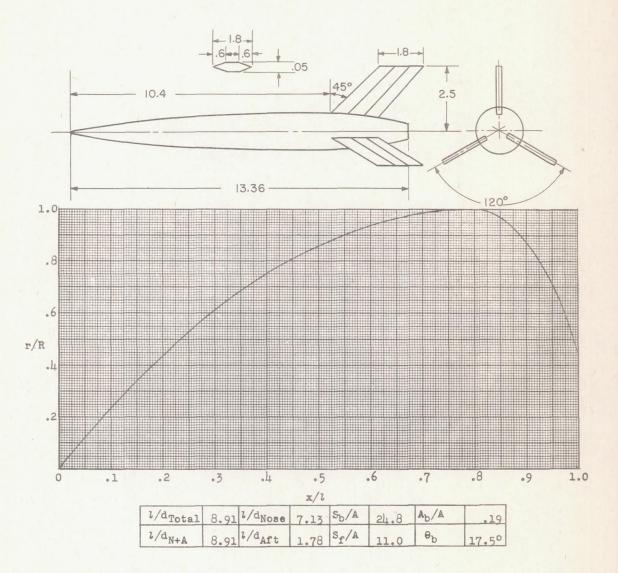


Figure 87.- Concluded.



Test: Helium Gun

Figure 88.

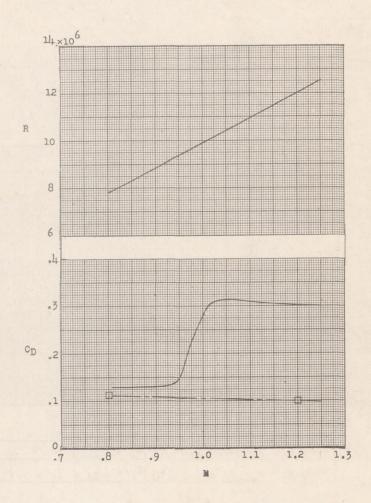
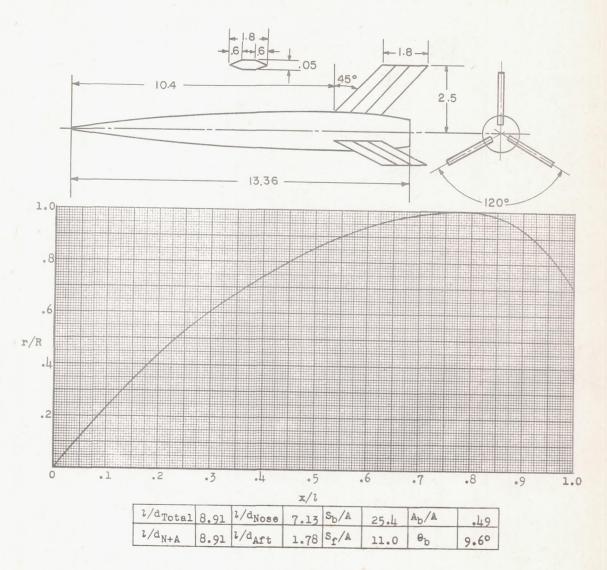


Figure 88. - Concluded.



Designation: 81

Test: Helium Gun

Remarks: Parabolic nose and afterbody.

Figure 89.

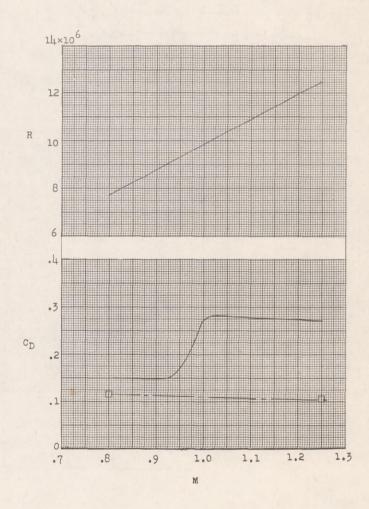
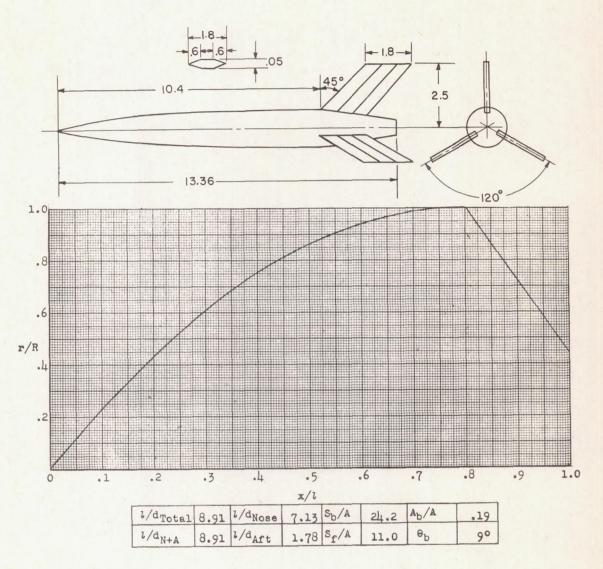


Figure 89.- Concluded.



Test: Helium Gun

Remarks: Parabolic nose; conical afterbody.

Figure 90.

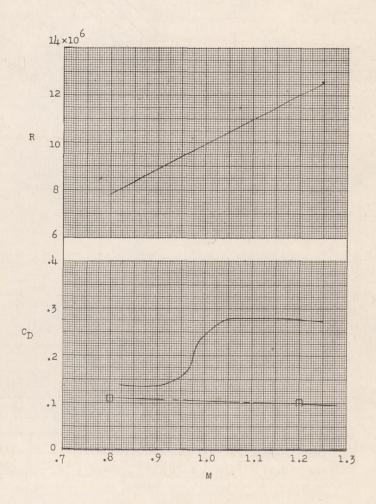
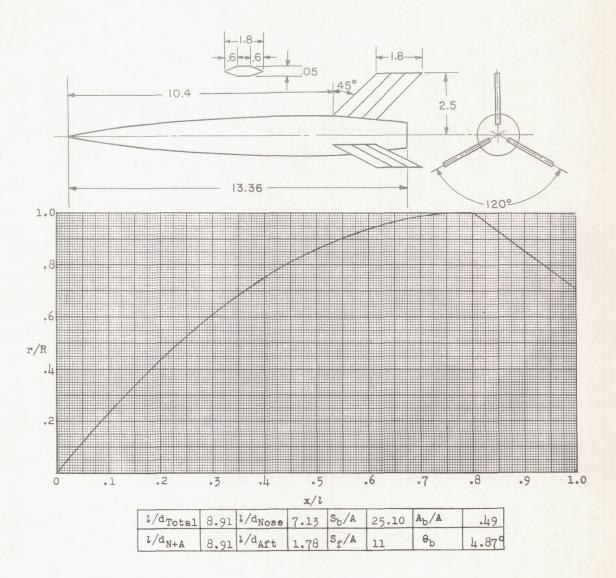


Figure 90. - Concluded.



Test: Helium Gun

Figure 91.

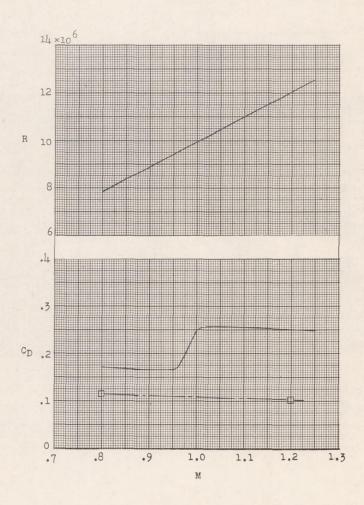
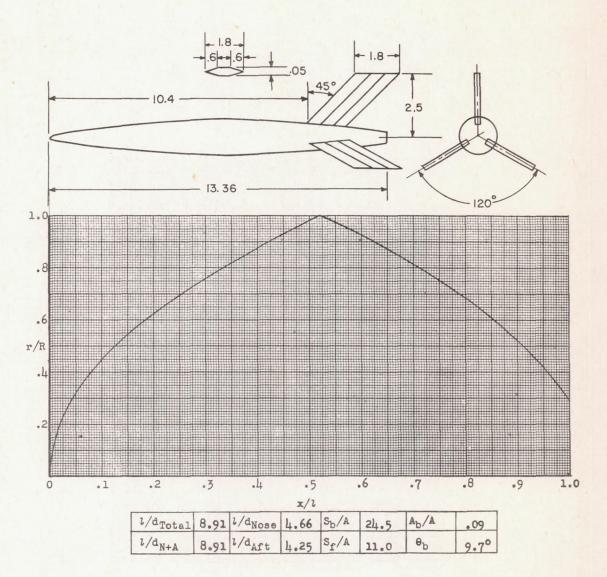


Figure 91.- Concluded.



Test: Helium Gun

Remarks: Contour of nose and afterbody exactly the same as those of configuration 85 (fig. 93).

Figure 92.

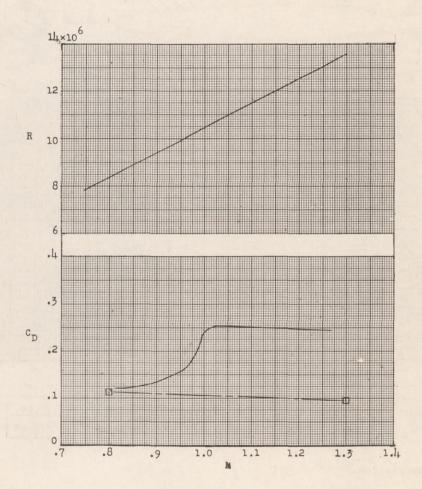
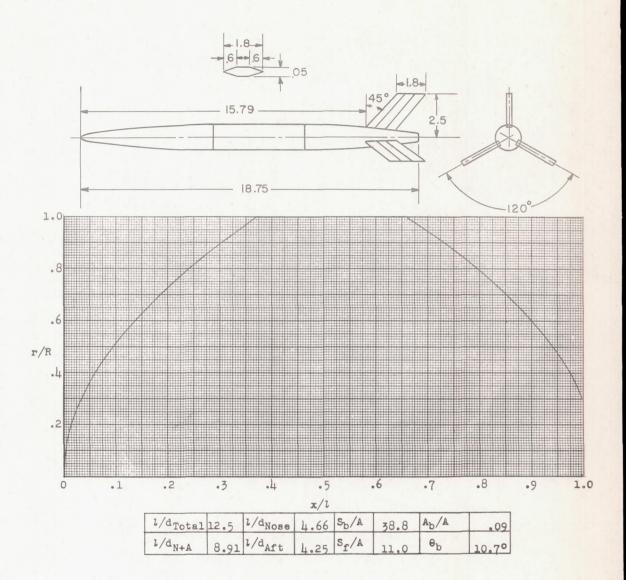


Figure 92. - Concluded.



Test: Helium Gun

Remarks: Contour of nose and afterbody exactly the same as configuration 84 (fig. 92).

Figure 93.

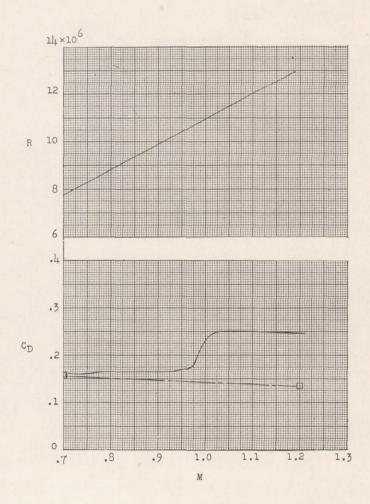
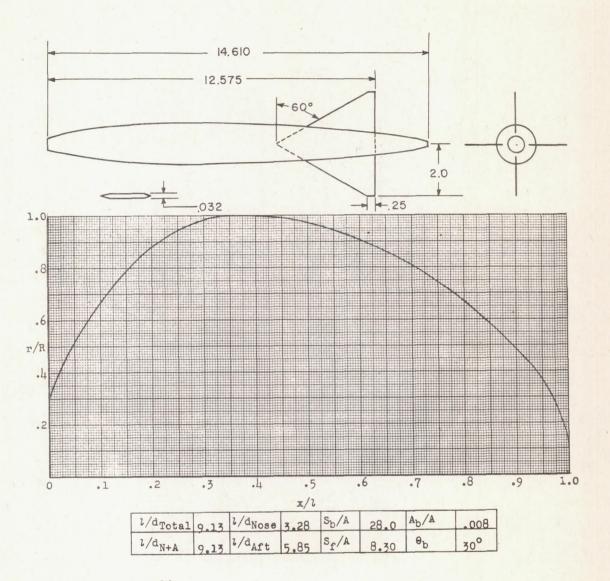


Figure 93. - Concluded.



Test: Helium Gun

Remarks: Flat face of model caused high subsonic drag. (See also configuration 47 (fig. 55).)

Figure 94.

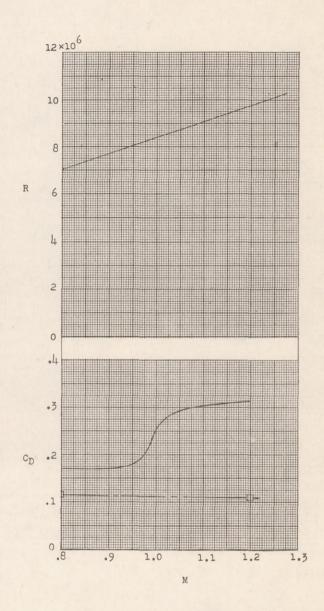
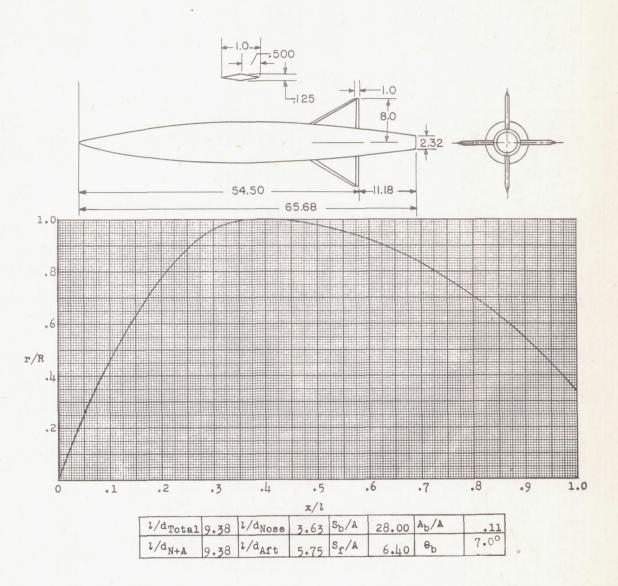
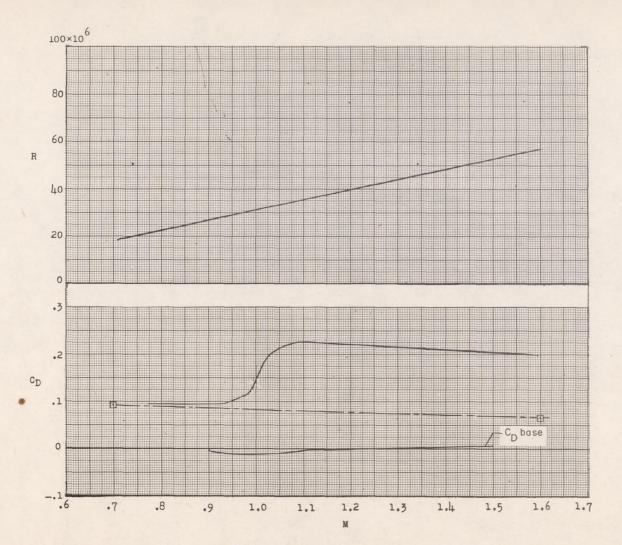


Figure 94. - Concluded.



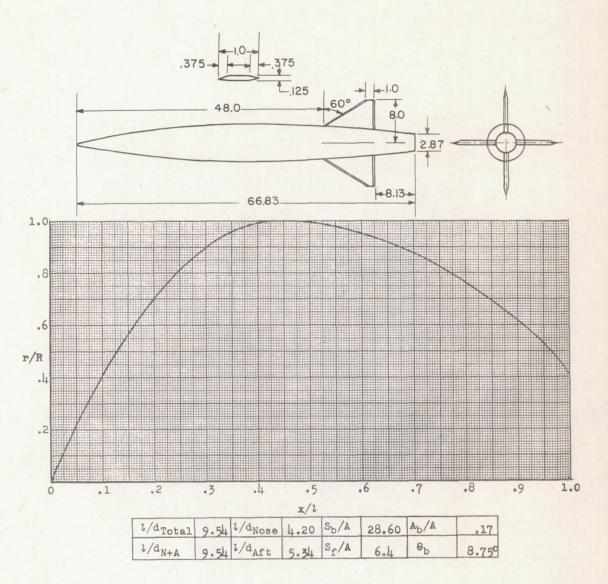
Test: Rocket

Figure 95.



Remarks: Parabolic nose and afterbody.

Figure 95.



Test: Rocket

Figure 96.

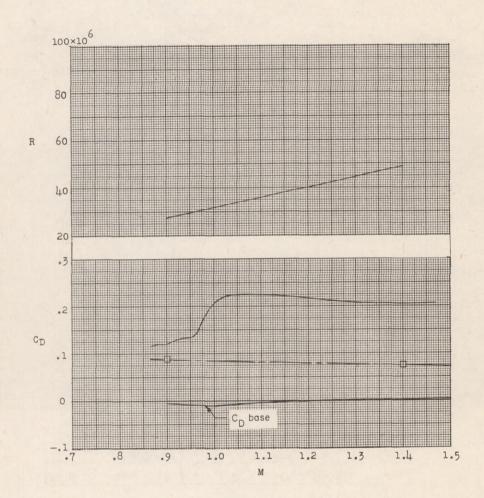
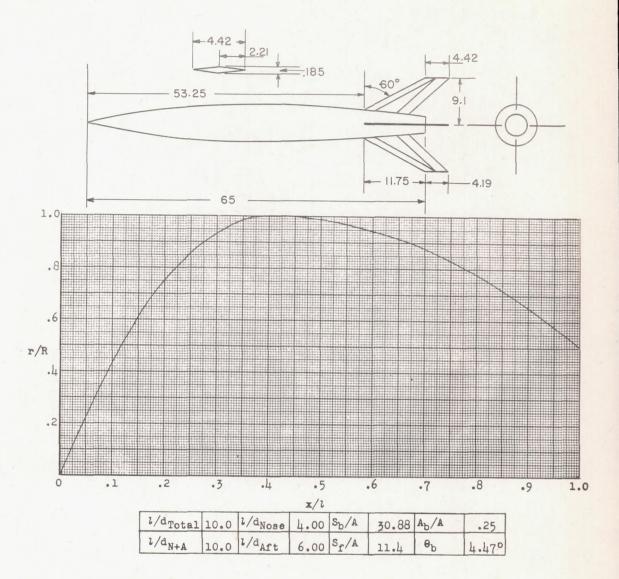
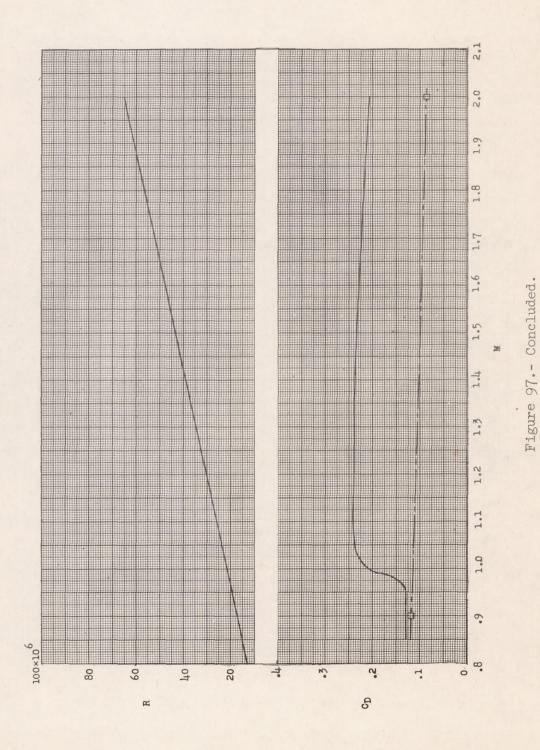


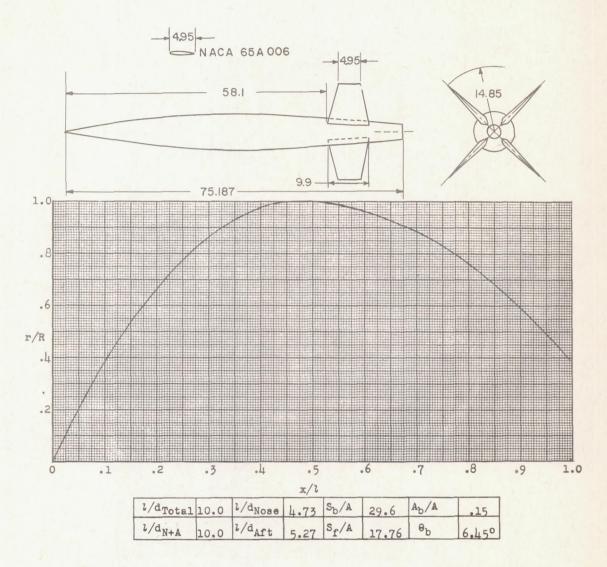
Figure 96.- Concluded.



Test: Rocket

Figure 97.





Test: Rocket

Figure 98.

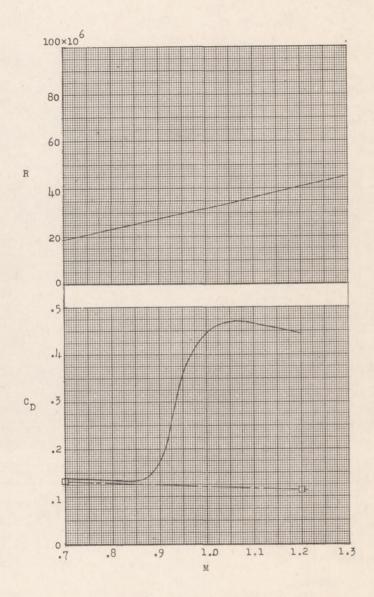
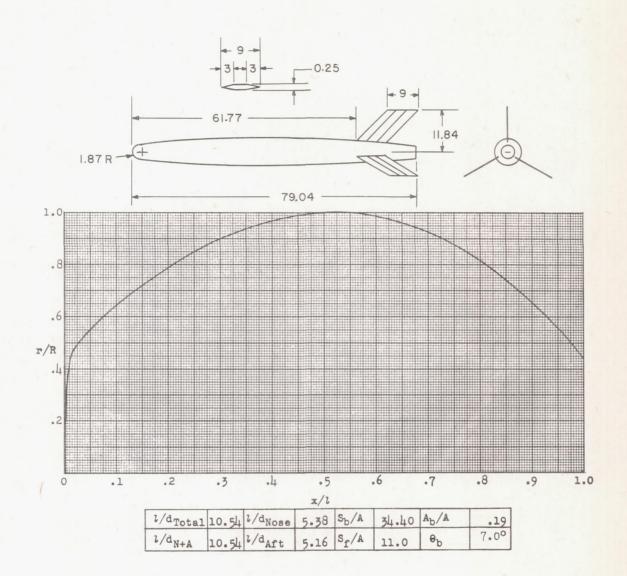


Figure 98.- Concluded.



Test: Rocket

Remarks: Nose consists of hemispherical and parabolic segments; parabolic afterbody.

Figure 99.

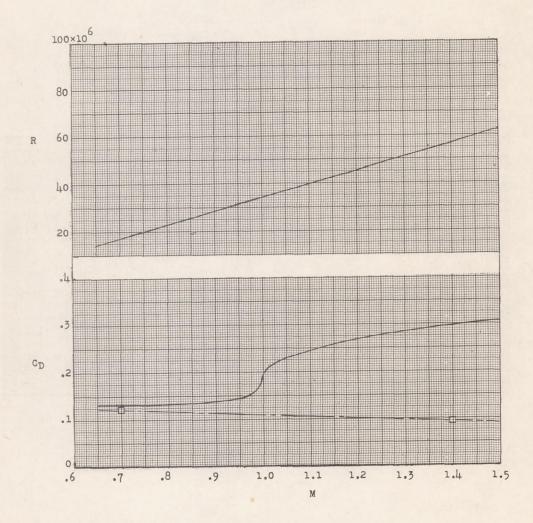
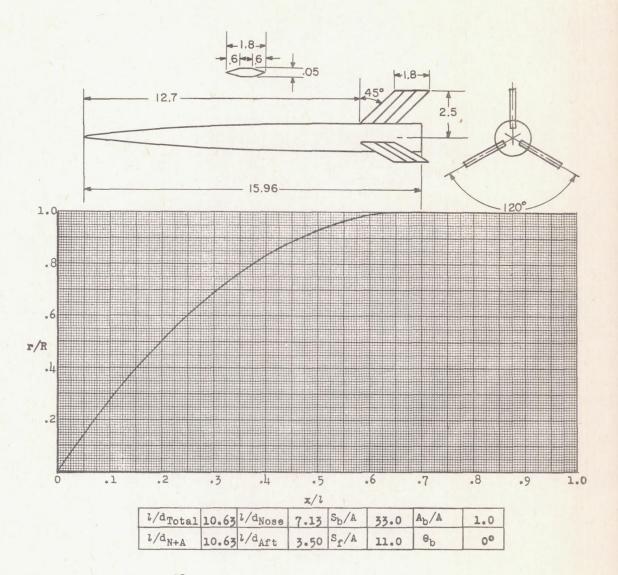


Figure 99.- Concluded.



Designation: 92

Test: Helium Gun

Remarks: Parabolic nose; cylindrical afterbody.

Figure 100.

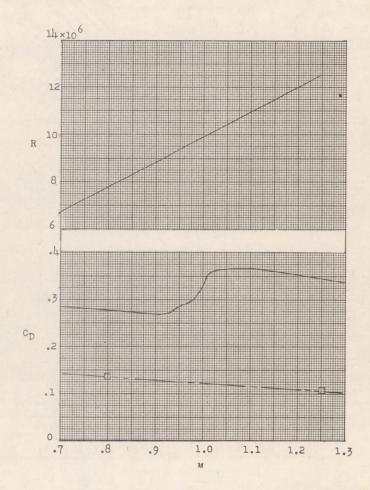
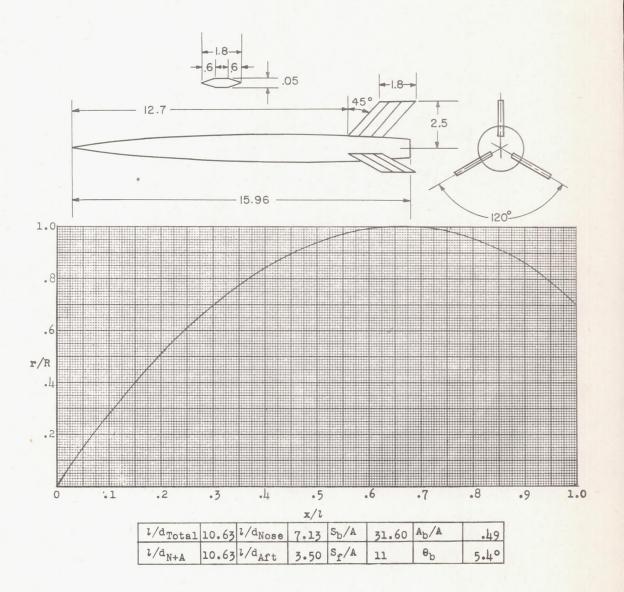


Figure 100. - Concluded.



Test: Helium Gun

Figure 101.

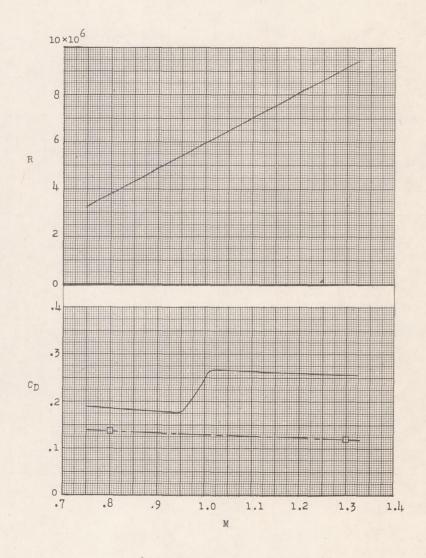
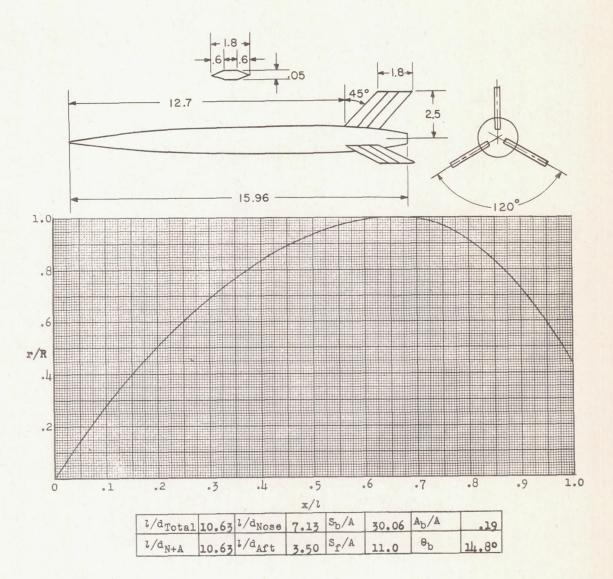


Figure 101. - Concluded.



Test: Helium Gun

Figure 102.

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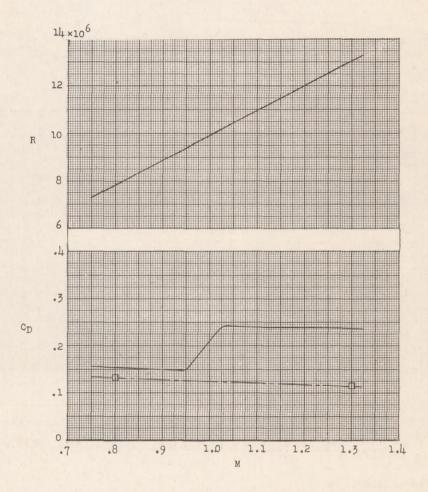
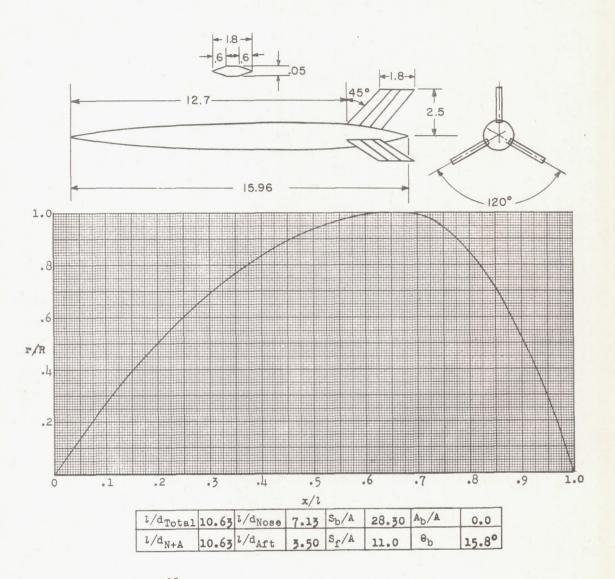


Figure 102. - Concluded.



Test: Helium Gun

Figure 103.

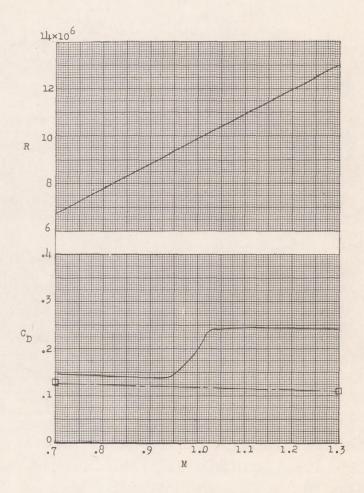
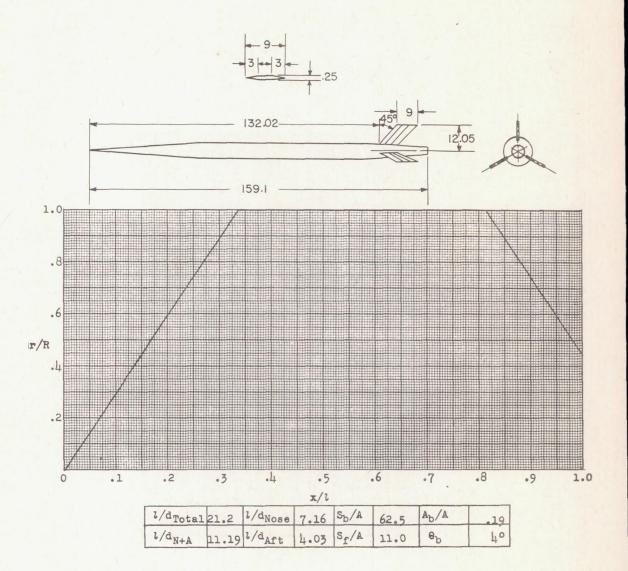


Figure 103. - Concluded.



Designation: 96

Test: Rocket

Remarks: Conical nose and afterbody.

Figure 104.

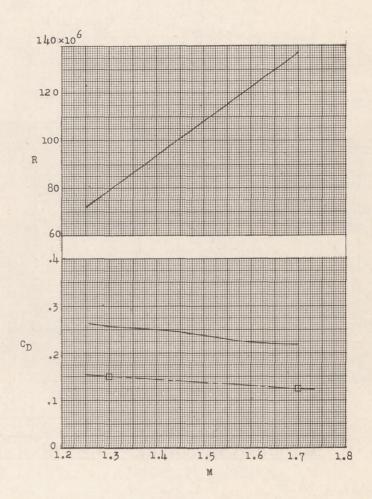
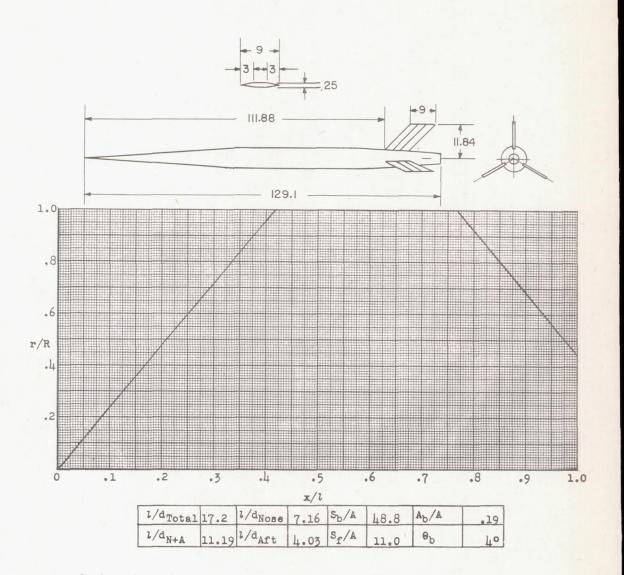


Figure 104. - Concluded.



Test: Rocket

Remarks: Conical nose and afterbody.

Figure 105.

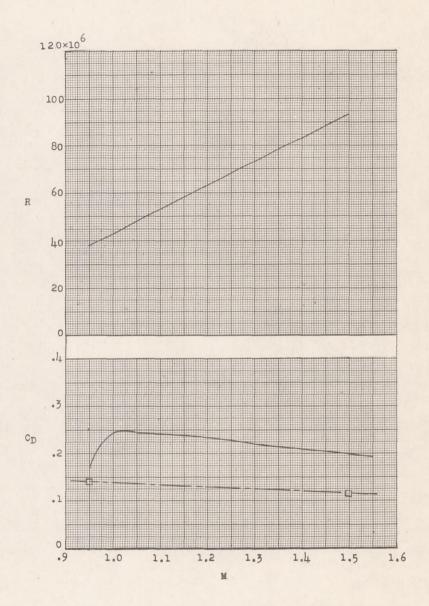
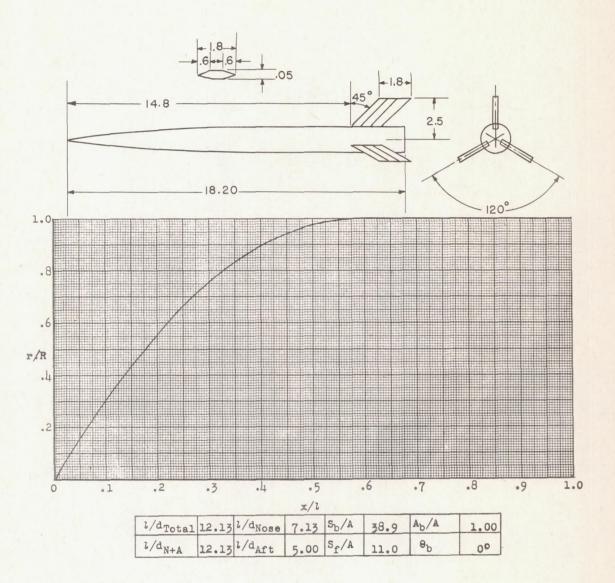


Figure 105. - Concluded.



Test: Helium Gun

Remarks: Parabolic nose; cylindrical afterbody.

Figure 106.

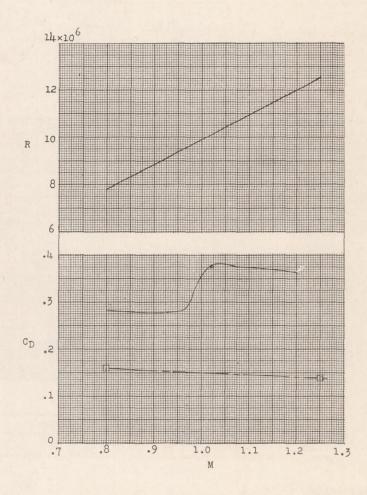
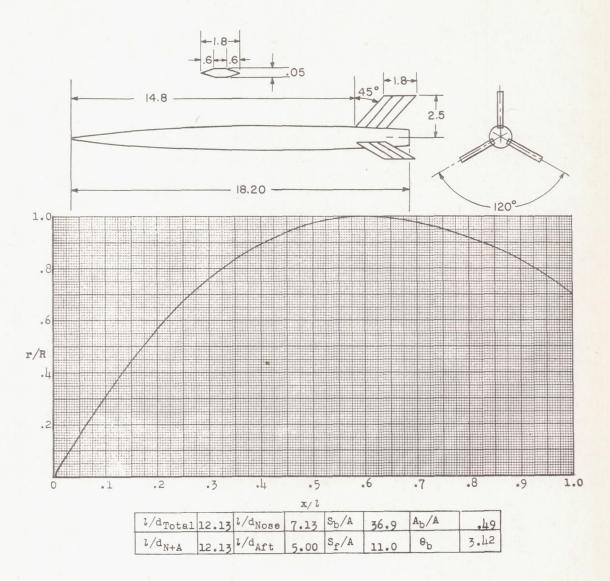


Figure 106.- Concluded.

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Designation: 99

Test: Helium Gun

Figure 107.

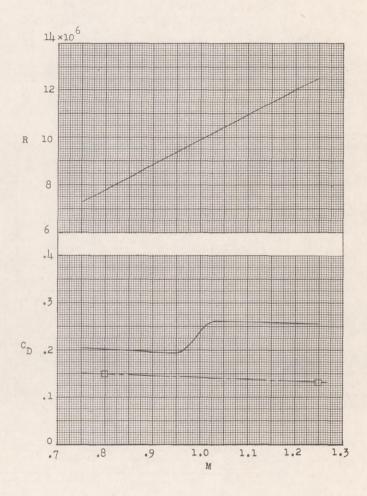
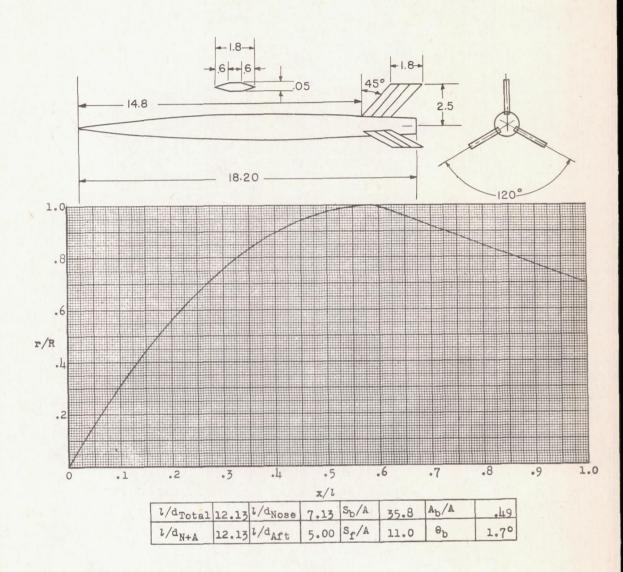


Figure 107. - Concluded.



Test: Helium Gun

Remarks: Parabolic nose; conical afterbody.

Figure 108.

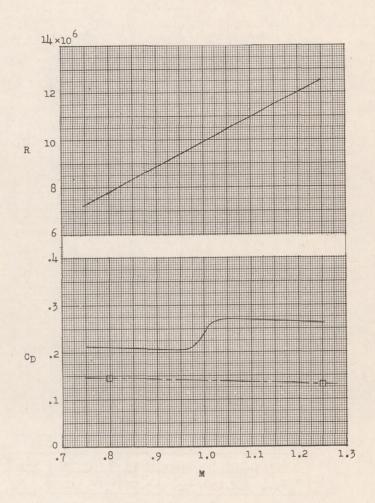
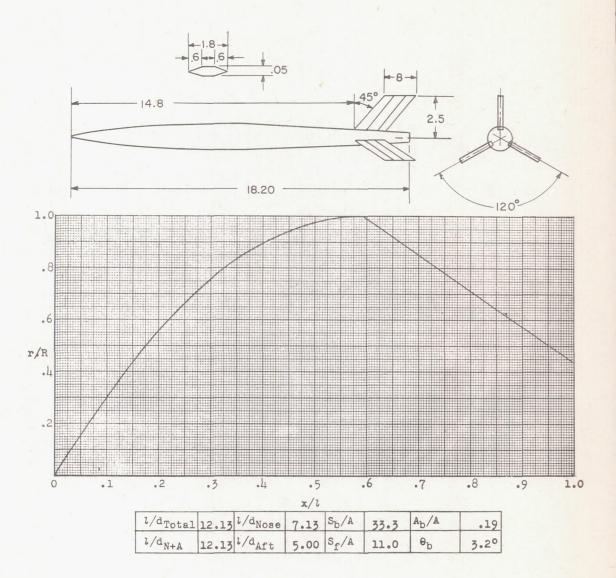


Figure 108. - Concluded.



Test: Helium Gun

Remarks: Parabolic nose; conical afterbody.

Figure 109.

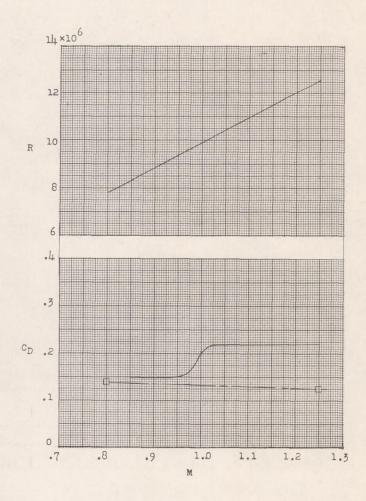
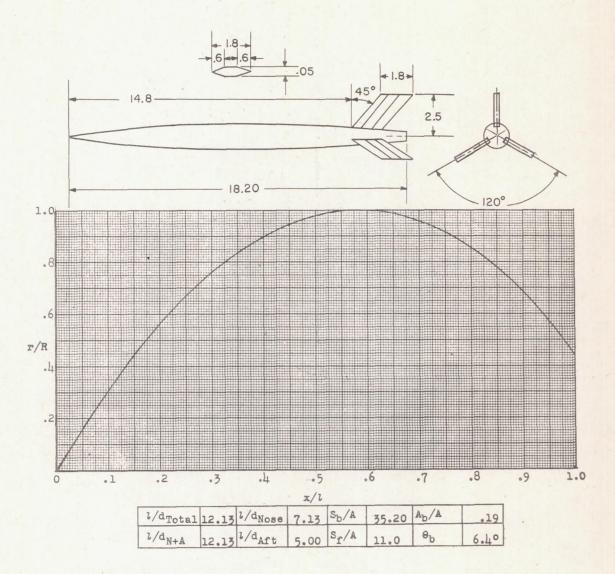


Figure 109. - Concluded.



Test: Helium Gun

Figure 110.

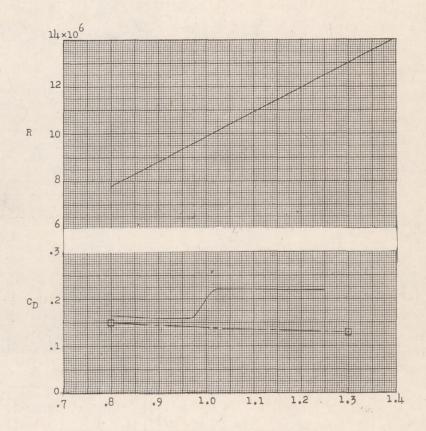
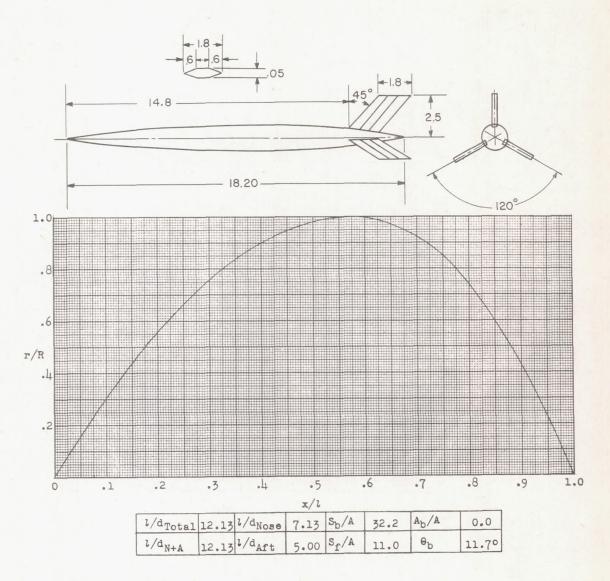


Figure 110. - Concluded.



Test: Helium Gun

Figure 111.

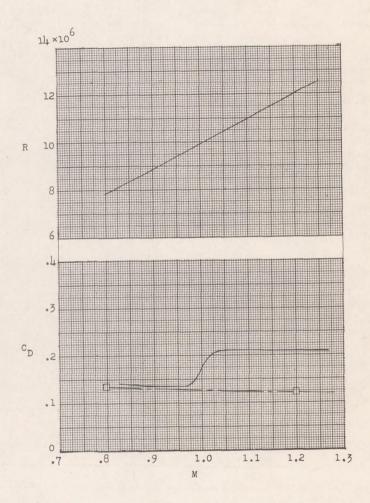
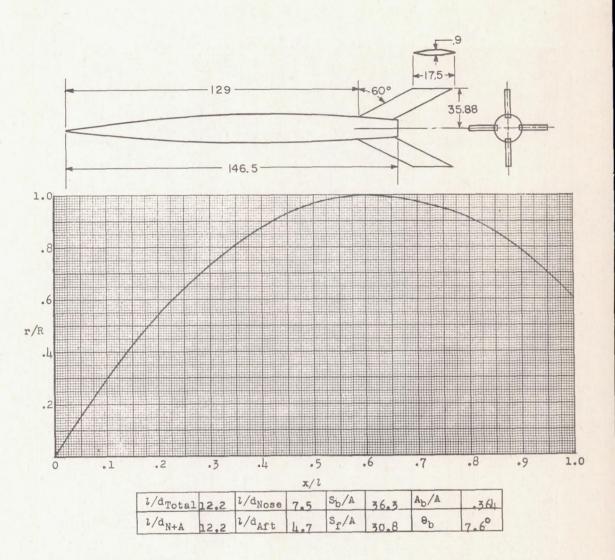


Figure 111. - Concluded.



Test: Rocket

Remarks: Parabolic nose and afterbody twice scale of model 105. Calculated friction drag coefficients are obviously too high. (See note for model 105 (fig. 113) about oscillations in drag curves.)

Figure 112.

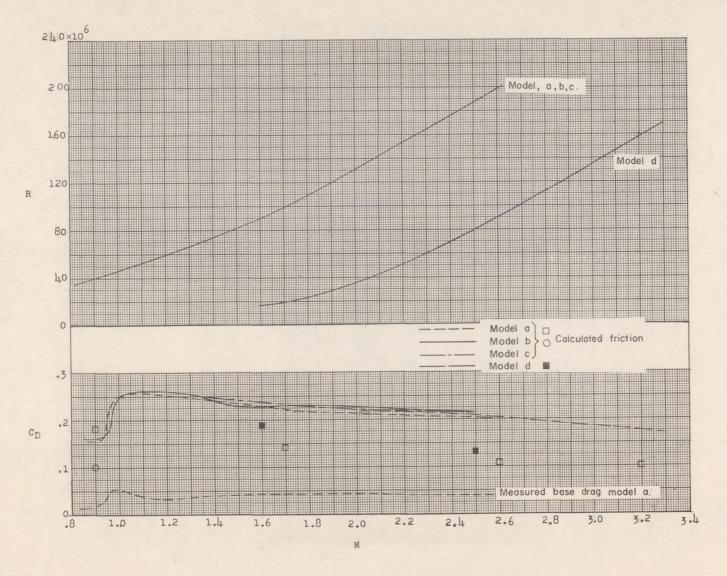
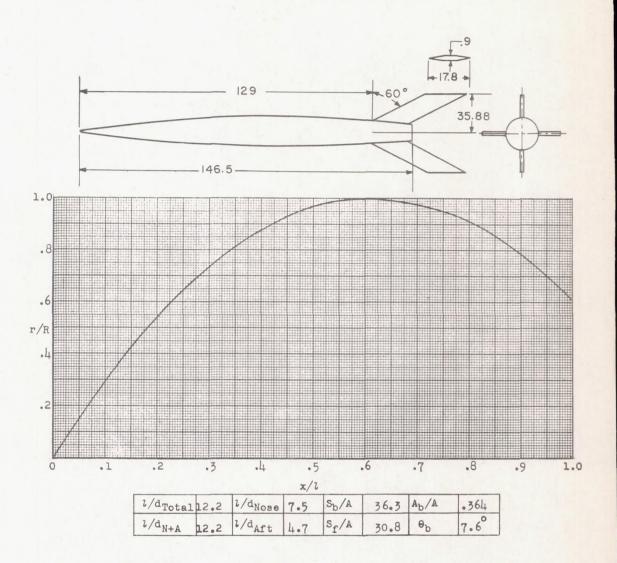


Figure 112. - Concluded.



Test: Rocket

Figure 113.

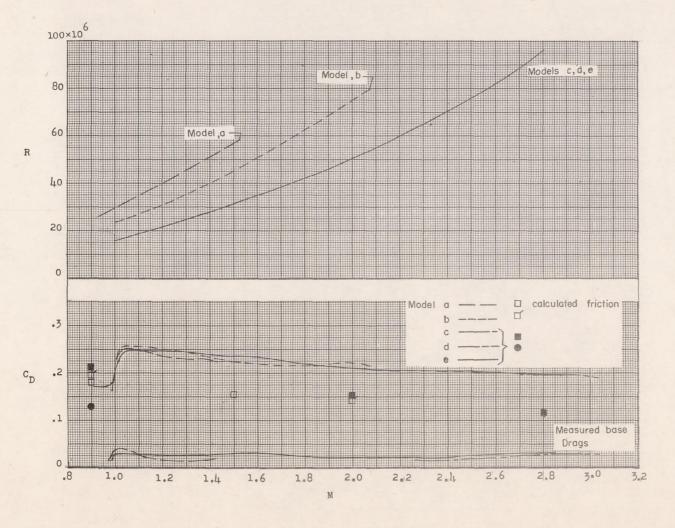
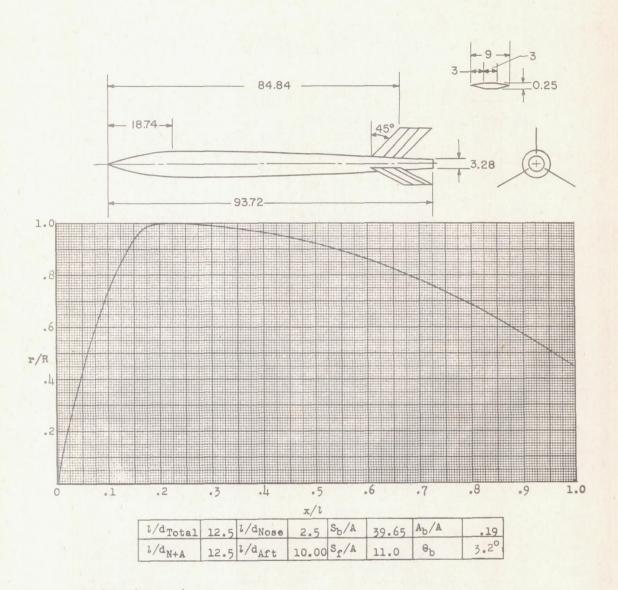


Figure 113. - Concluded.



Test: Rocket

Figure 114.

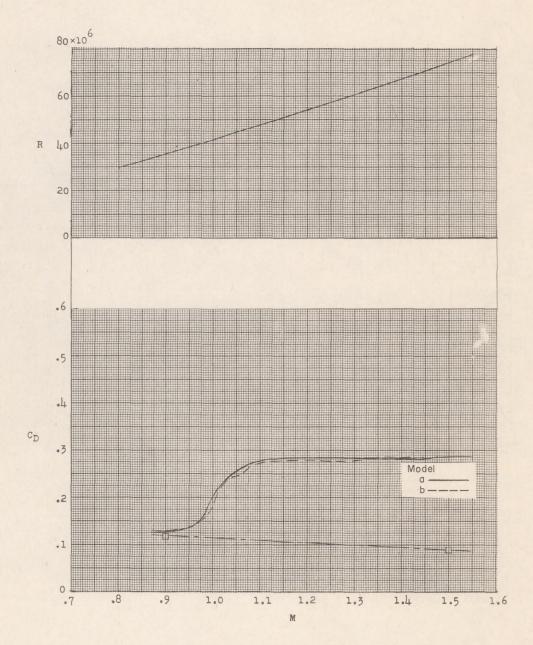
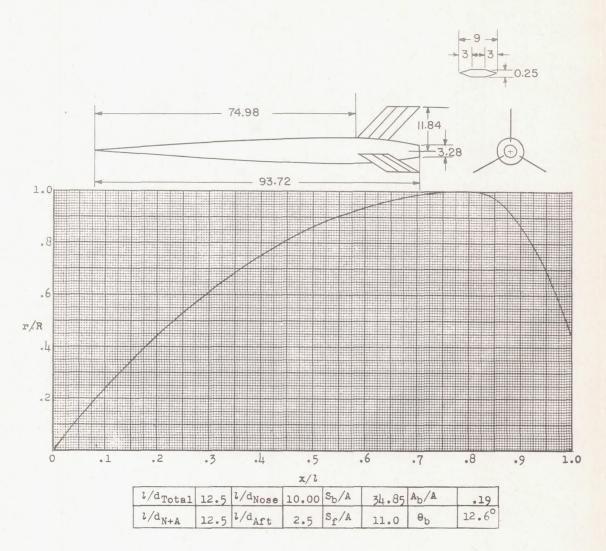


Figure 114.- Concluded.



Test: Rocket

Figure 115.

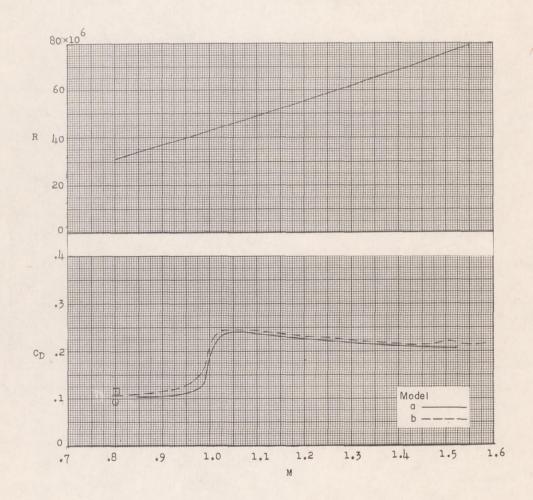
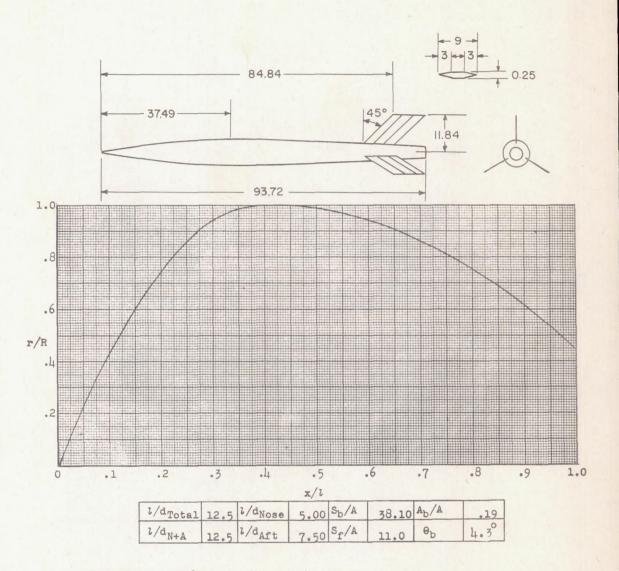


Figure 115. - Concluded.



Test: Rocket

Remarks: Parabolic nose and afterbody; both models appear to have been affected by rocket afterburning which caused the wavy curve of ${\tt C}_{\tt D}$ at supersonic Mach numbers.

Figure 116.

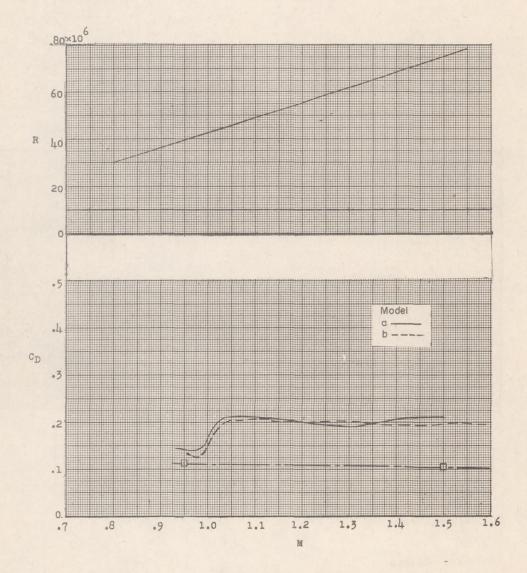
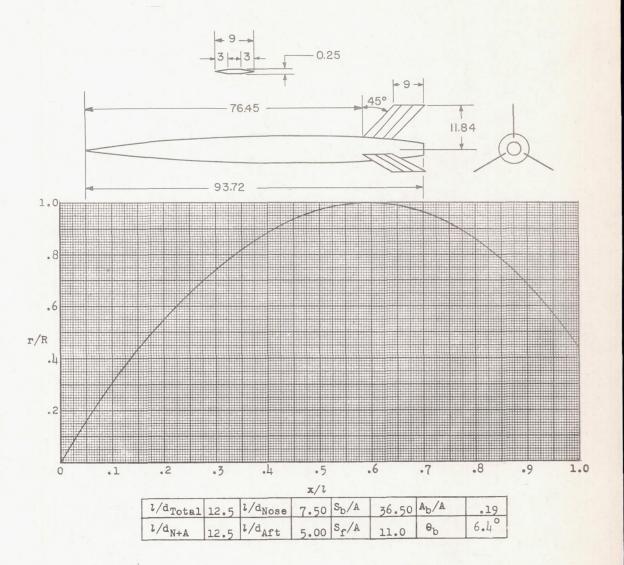


Figure 116.- Concluded.



Test: Rocket

Figure 117.

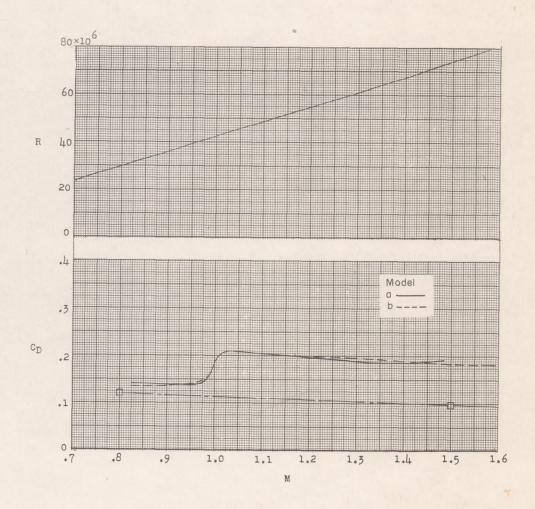
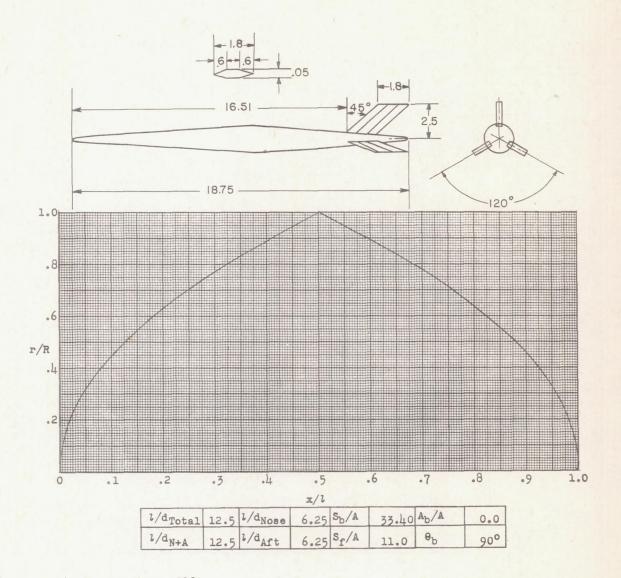


Figure 117. - Concluded.



Test: Helium Gun

Remarks: Nose and afterbody, $r' = x'^{\frac{3}{4}}$.

Figure 118.

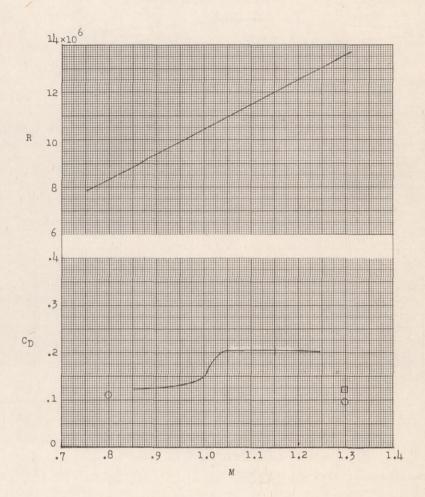
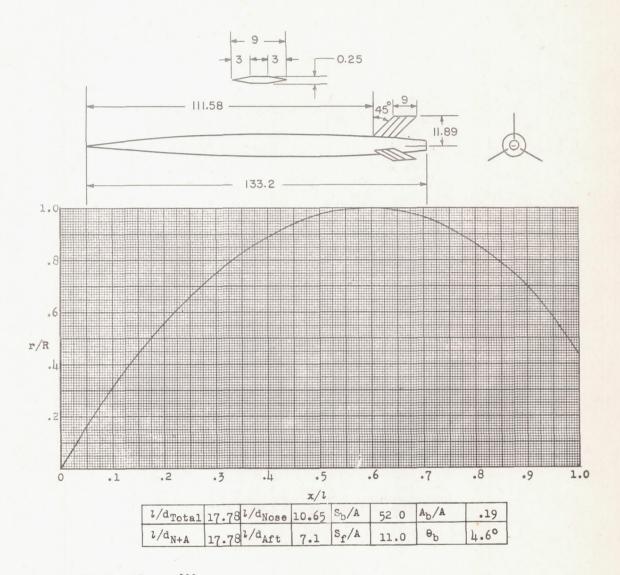


Figure 118.- Concluded.



Test: Rocket

Figure 119.

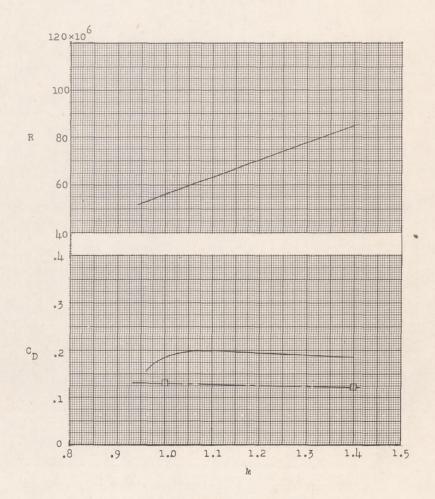
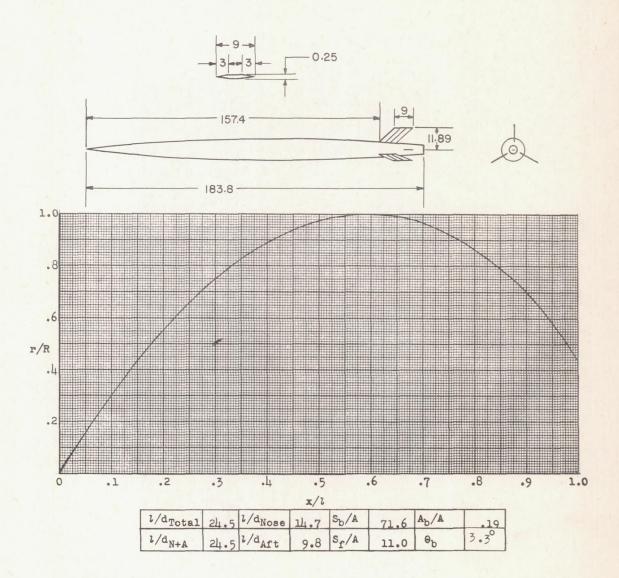


Figure 119. - Concluded.



Designation: 112

Test: Rocket

Figure 120.

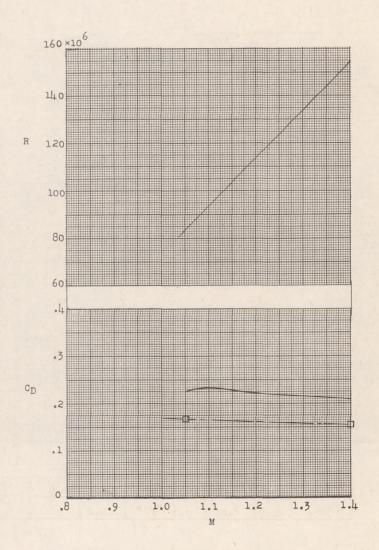
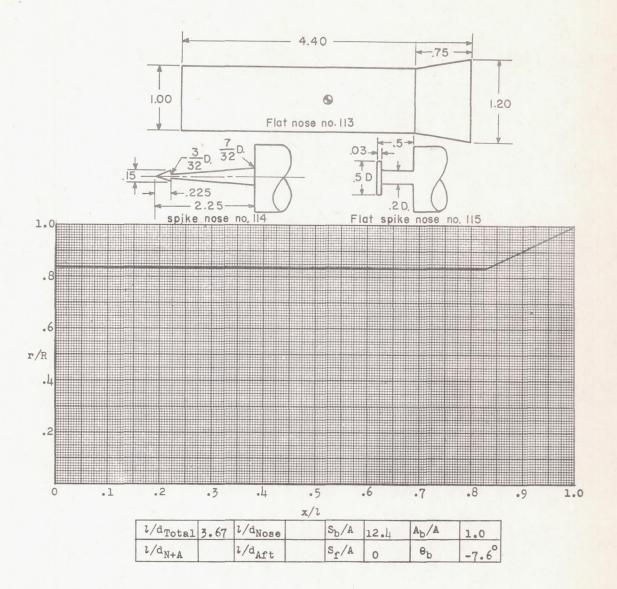


Figure 120. - Concluded.



Designation: 113-114-115

Test: Helium Gun

Remarks: Curves presented are faired values obtained from the drag of two models for each of the configurations. In each case the drags of the identical models were quite close, indicating that the models were at essentially 0° angle of attack since it does not appear reasonable that the drag due to oscillations would be a repeatable phenomena.

Figure 121.

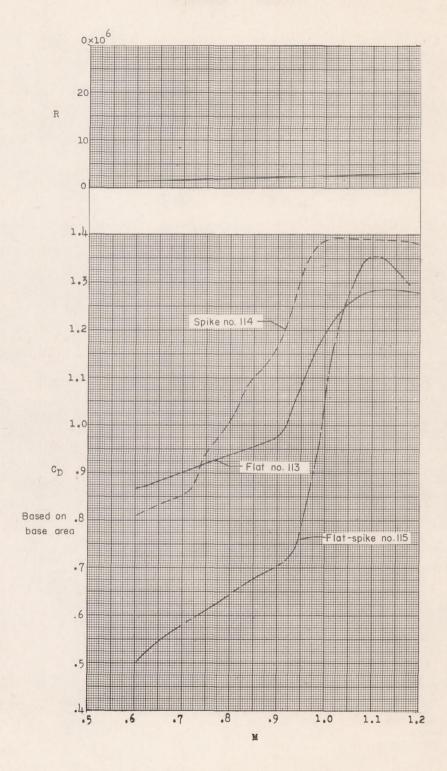
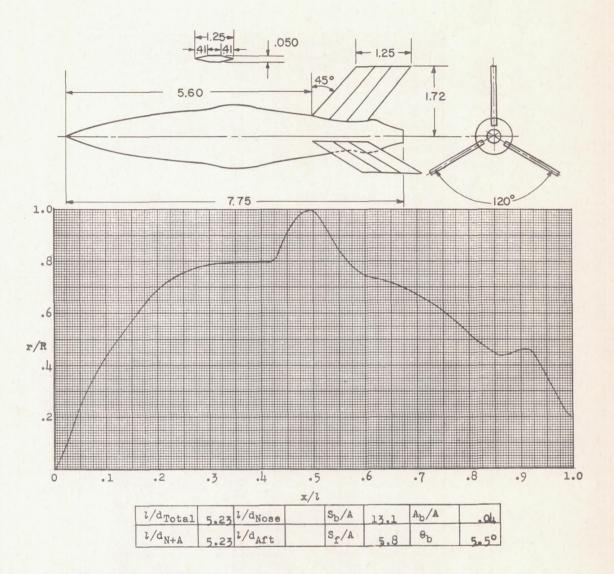


Figure 121. - Concluded.



Test: Helium Gun

Figure 122.

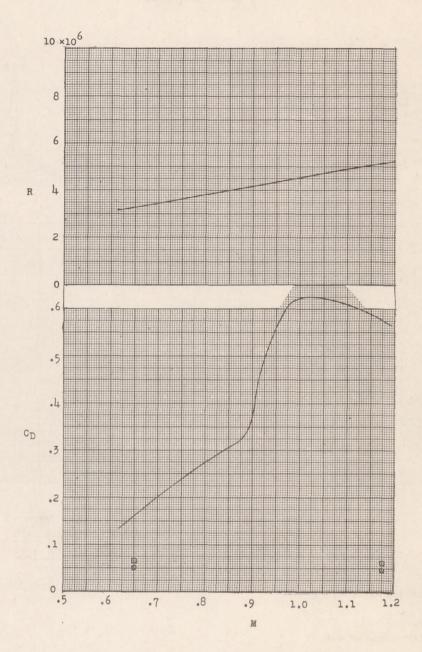
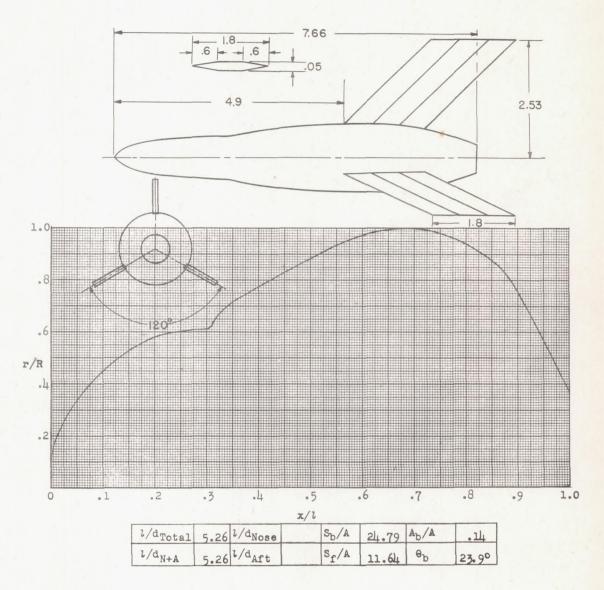


Figure 122. - Concluded.



Test: Helium Gun

Figure 123.

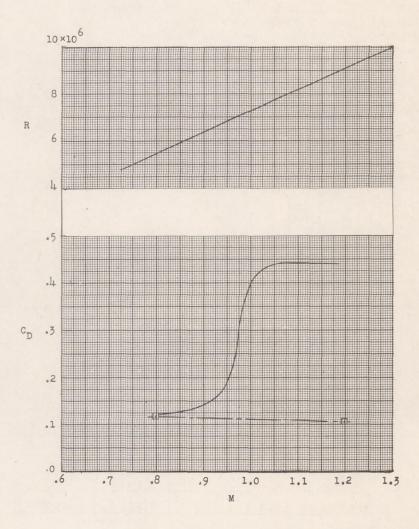


Figure 123. - Concluded.

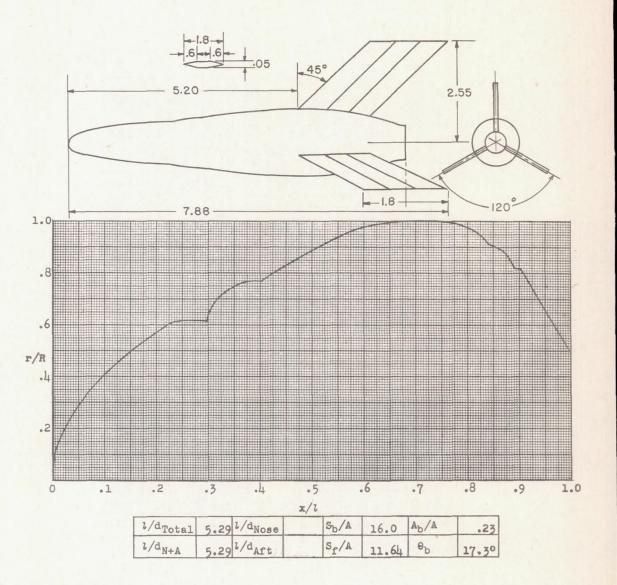


Figure 124.

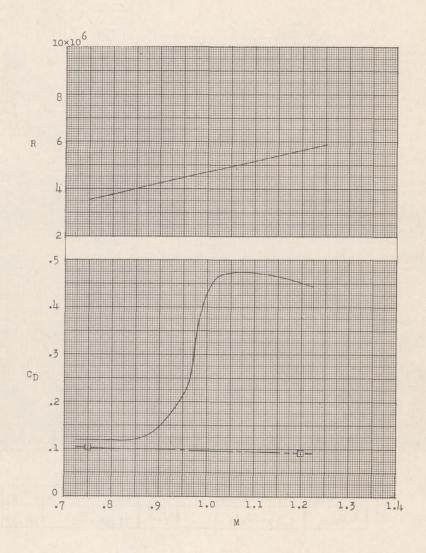


Figure 124. - Concluded.

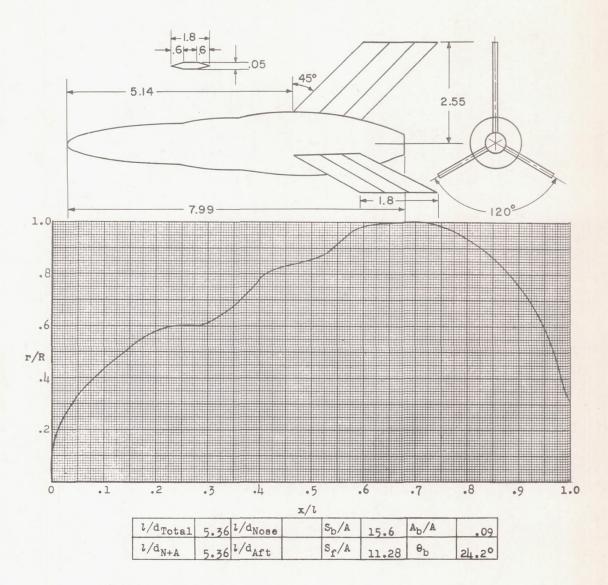


Figure 125.

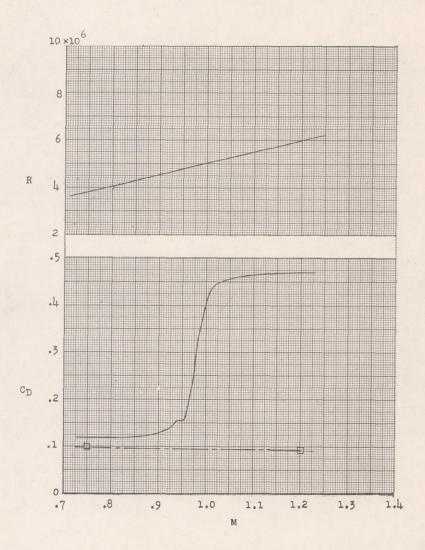


Figure 125. - Concluded.

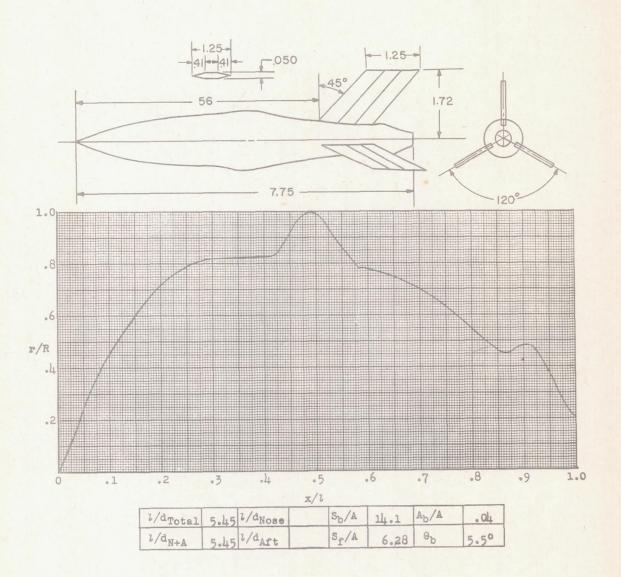


Figure 126.

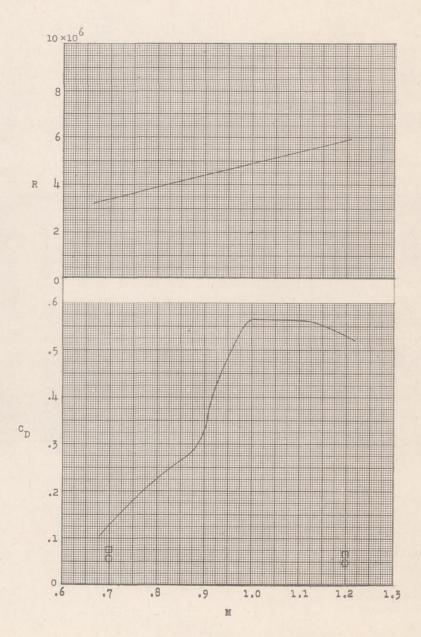
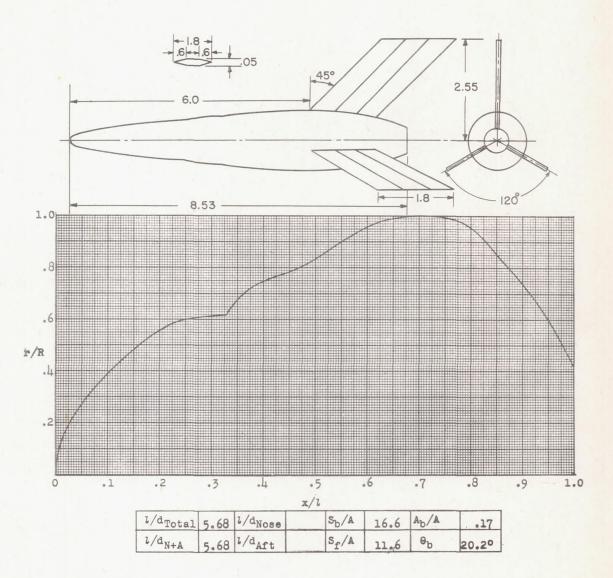


Figure 126. - Concluded.



Designation: 121

Test: Helium Gun

Figure 127.

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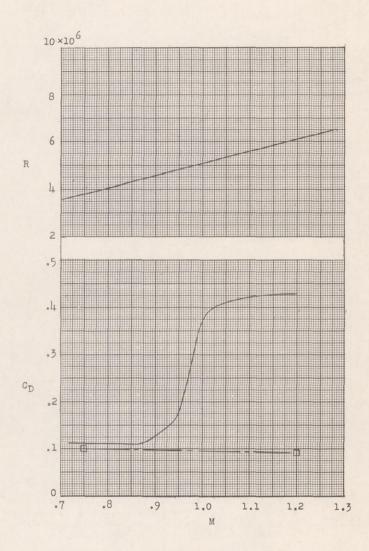
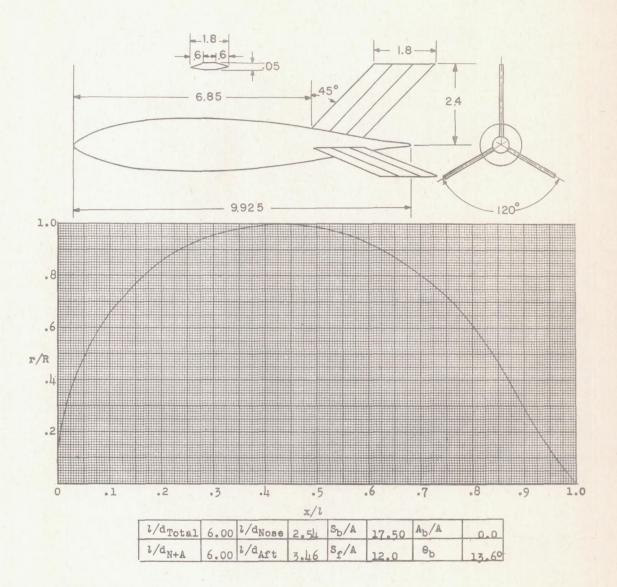


Figure 127. - Concluded.



Designation: 122

Test: Helium Gun

Figure 128.

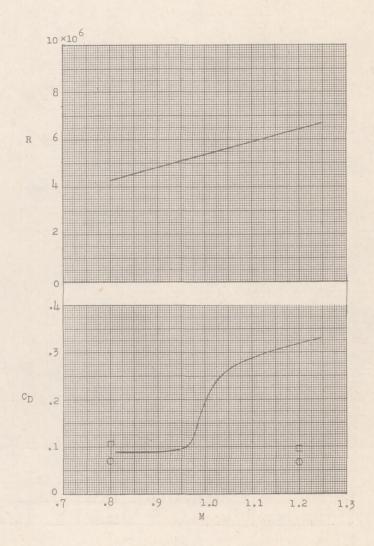
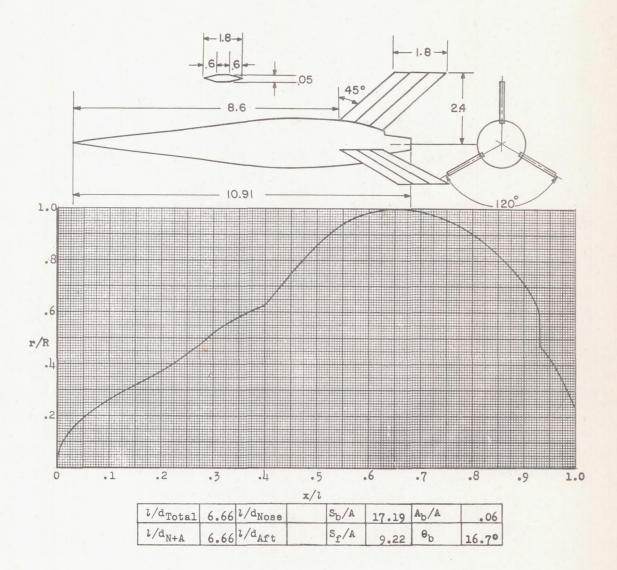


Figure 128. - Concluded.



Test: Helium Gun

Remarks: Subsonic flow probably separated at rear step.

Figure 129.

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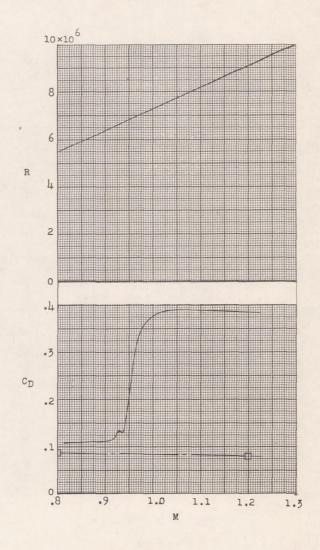
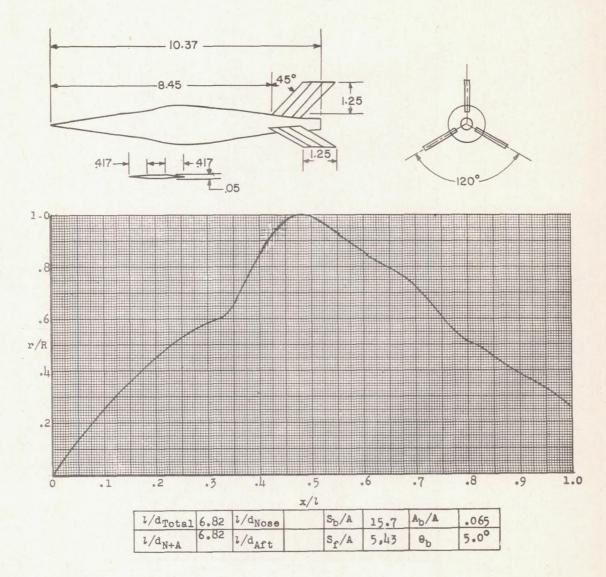


Figure 129. - Concluded.



Test: Helium Gun

Figure 130.

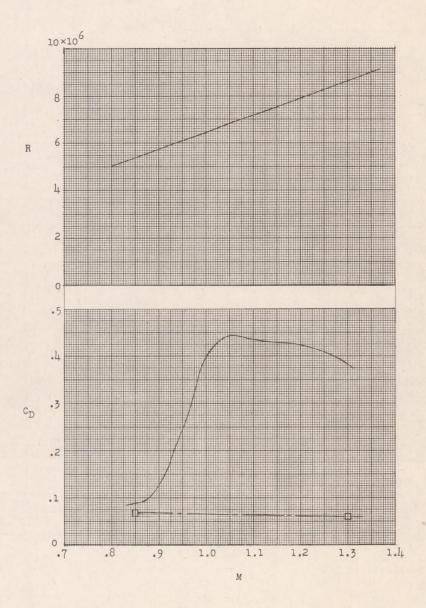
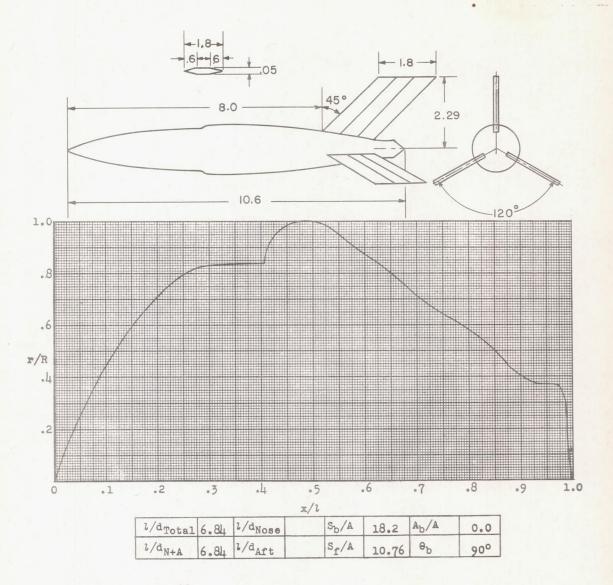


Figure 130. - Concluded.



Test: Helium Gun

Remarks: Although the calculated friction drag indicates that the fins may be in turbulent flow at subsonic values of M, it is possible that they may be in laminar as their low Reynolds number would predict. The drag difference between the laminar friction calculations and the experimental subsonic values may be due to separation over the base $\left(\frac{\mathbf{X}}{l} \approx 0.970\right)$ and over the forward step at $\frac{\mathbf{X}}{l} = 0.4$.

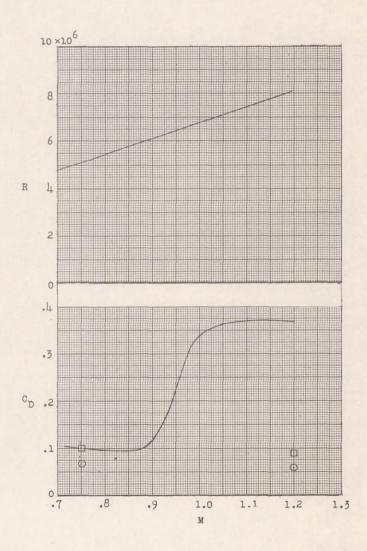


Figure 131. - Concluded.

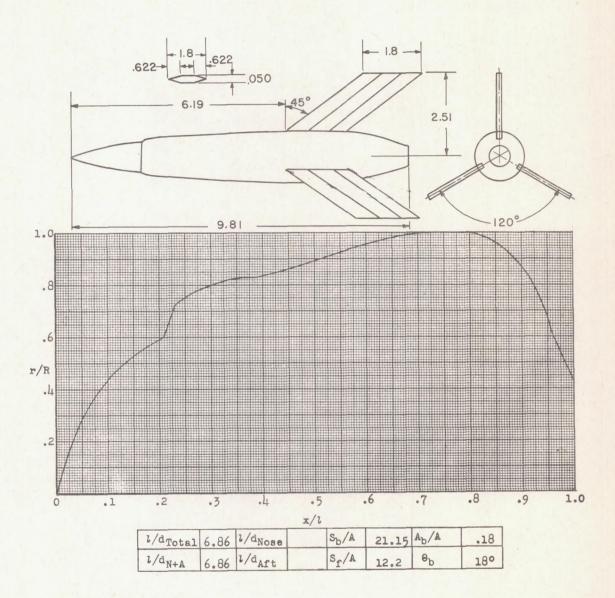


Figure 132.

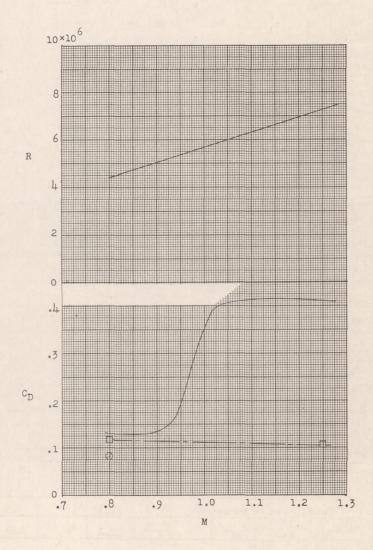
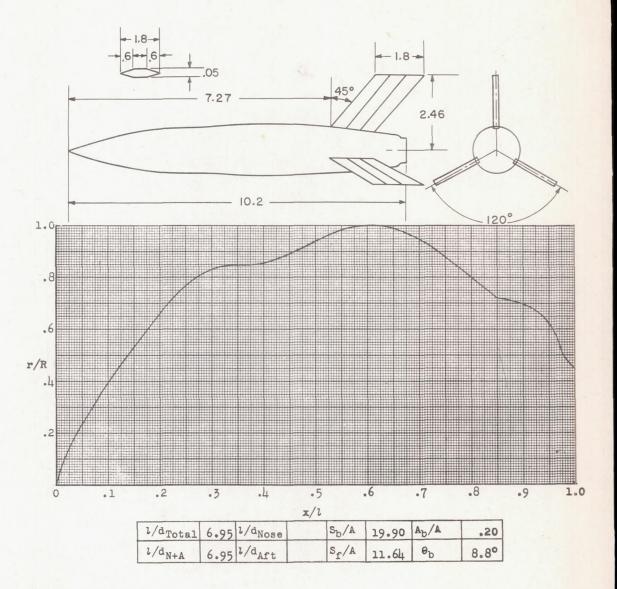


Figure 132. - Concluded.



Test: Helium Gun

Remarks: Assuming separation at step $\left(\frac{x}{l}\approx 0.9\right)$ and subsonic $C_{\rm p}$ = -0.1, the subsonic base drag would be $C_{\rm D_{base}}$ = 0.1 × 0.5 = 0.05. This would indicate that subsonic fin flow was laminar.

Figure 133.

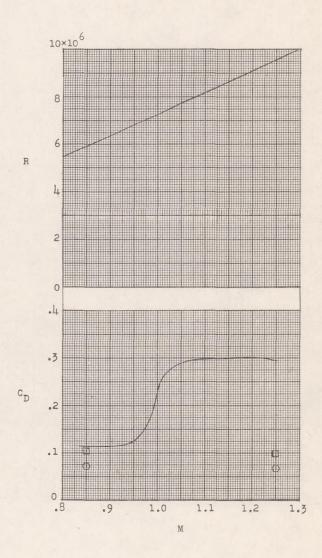


Figure 133. - Concluded.

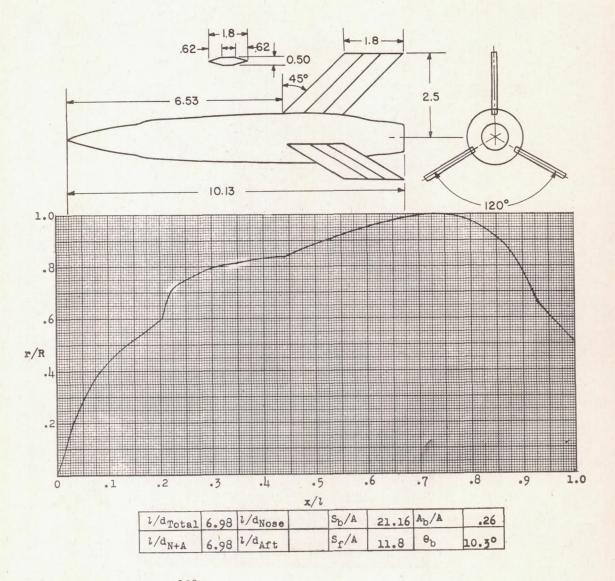


Figure 134.

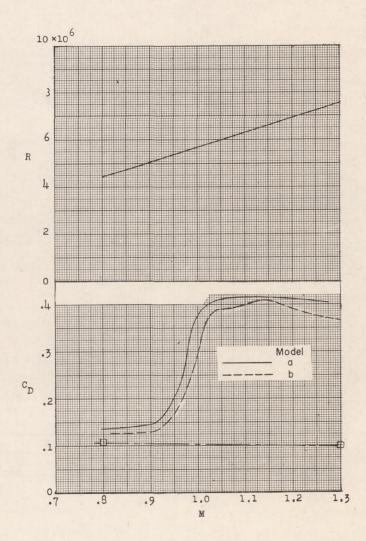
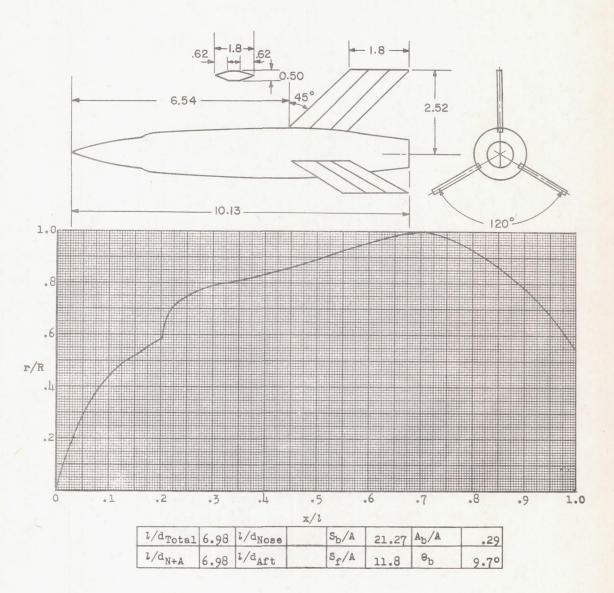


Figure 134. - Concluded.



Test: Helium Gun

Figure 135.

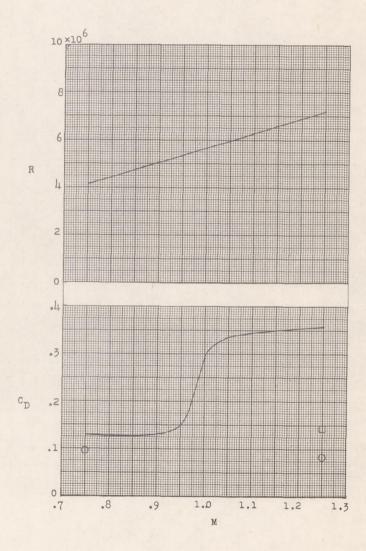
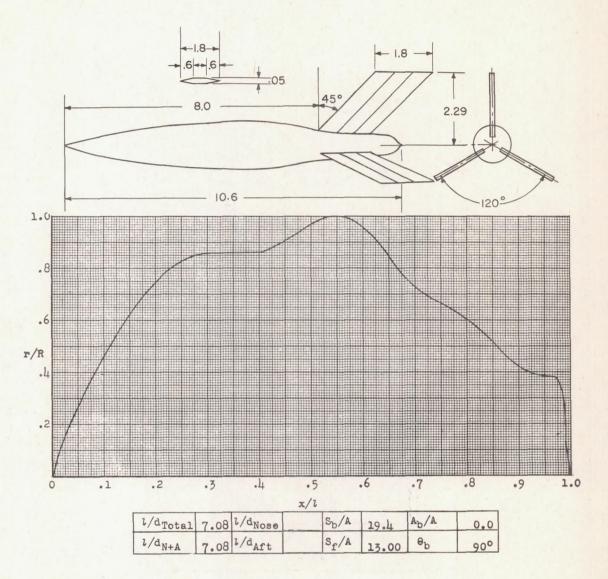


Figure 135. - Concluded.



Designation: 130

Test: Helium Gun

Remarks: Subsonic flow probably separated about $\frac{x}{l} = 0.97$.

Figure 136.

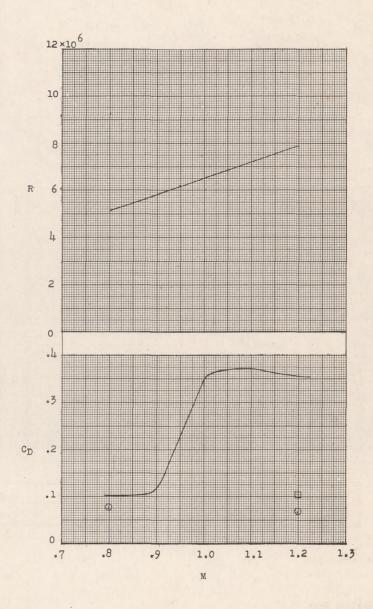
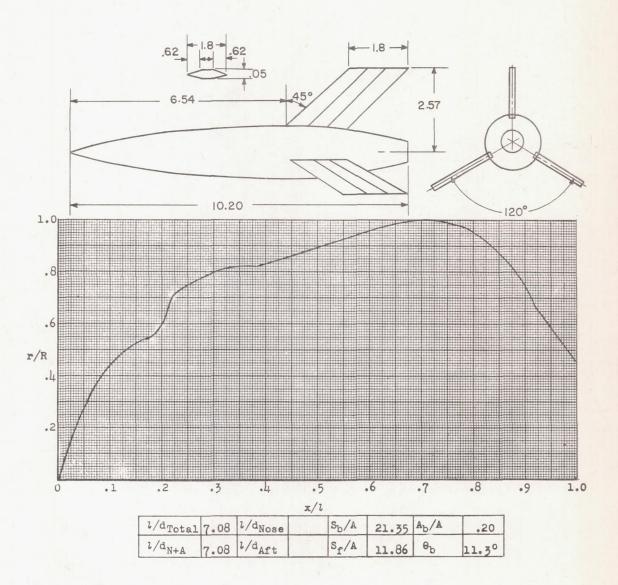


Figure 136.- Concluded.



Designation: 131

Test: Helium Gun

Figure 137.

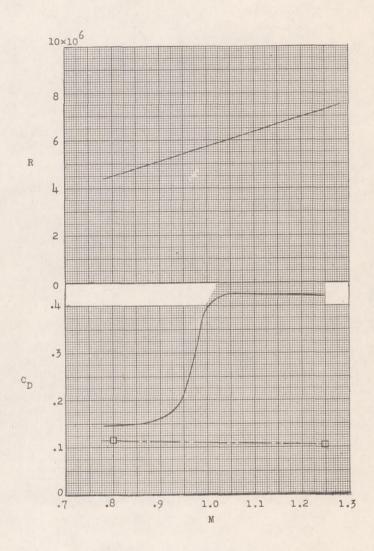
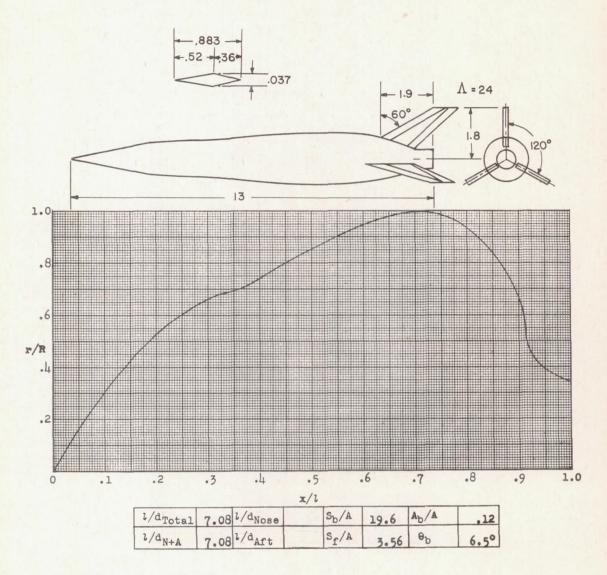


Figure 137. - Concluded.



Designation: 132

Test: Helium Gun

Figure 138.

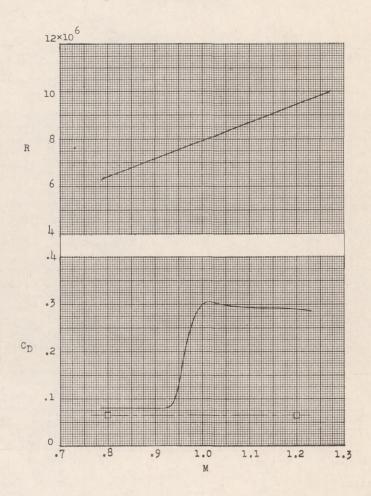
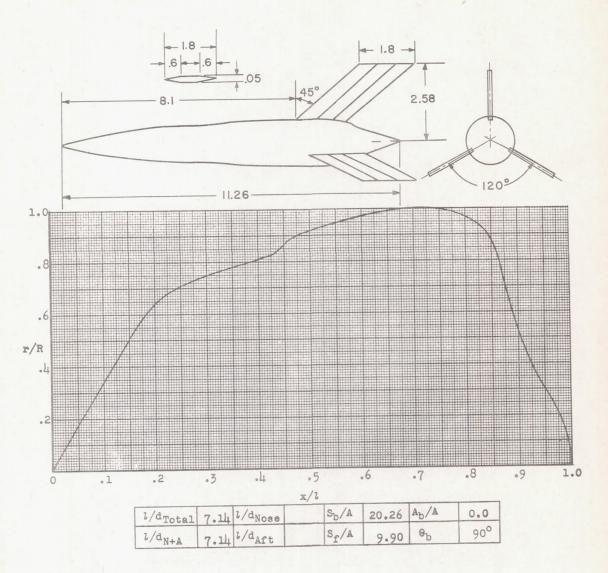


Figure 138. - Concluded.



Test: Helium Gun

Remarks: Flow is probably separated at subsonic speeds.

Figure 139.

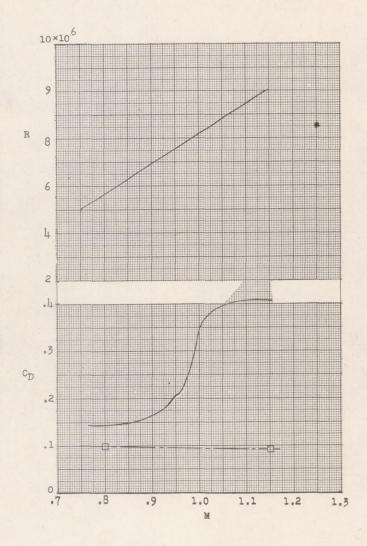
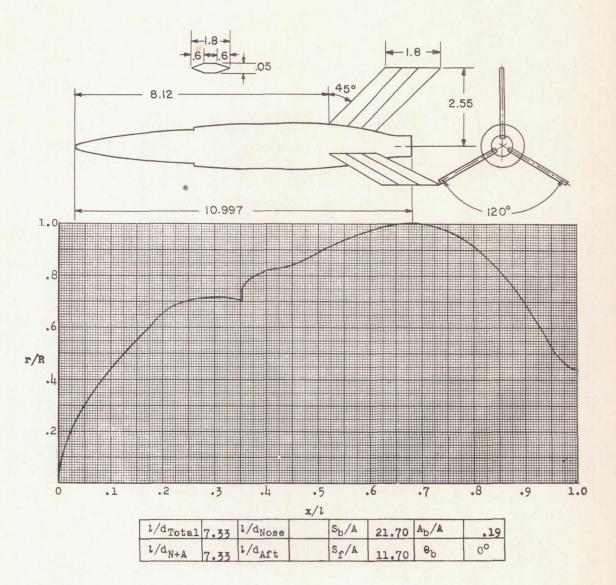


Figure 139. - Concluded.



Designation: 134

Test: Helium Gun

Remarks: Probable that subsonic flow was laminar. (See note for model 125 (fig. 131).)

Figure 140.

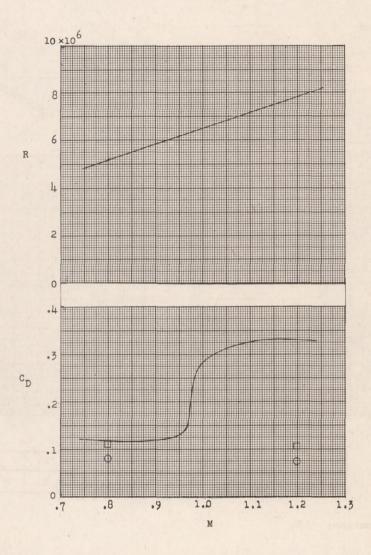
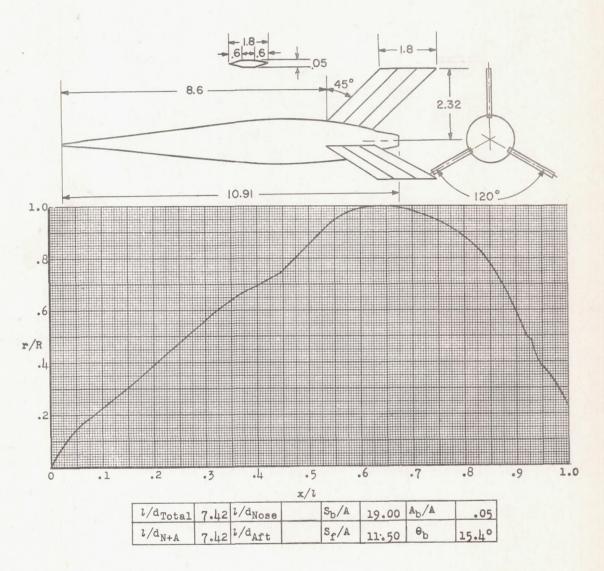


Figure 140. - Concluded.



Test: Helium Gun

Remarks: Subsonic drag looks too high.

Figure 141.

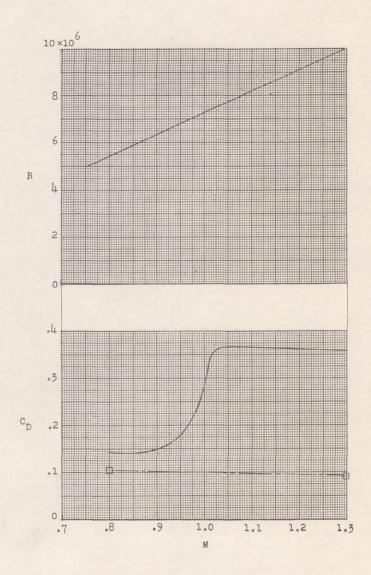


Figure 141. - Concluded.

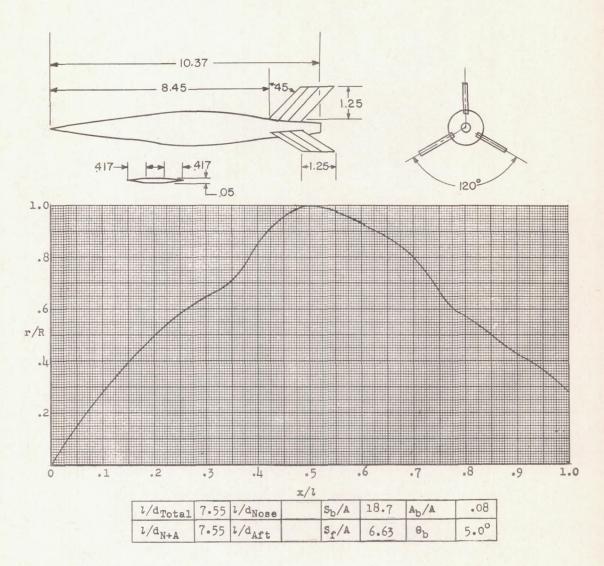


Figure 142.

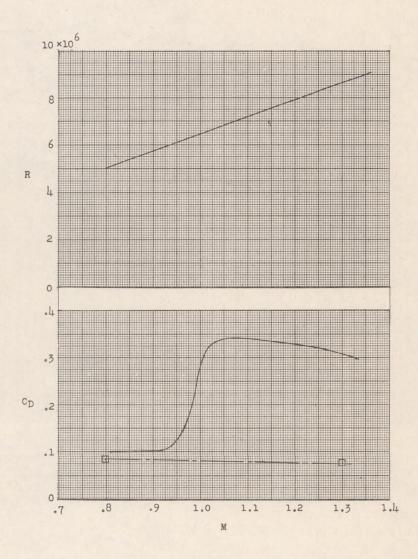
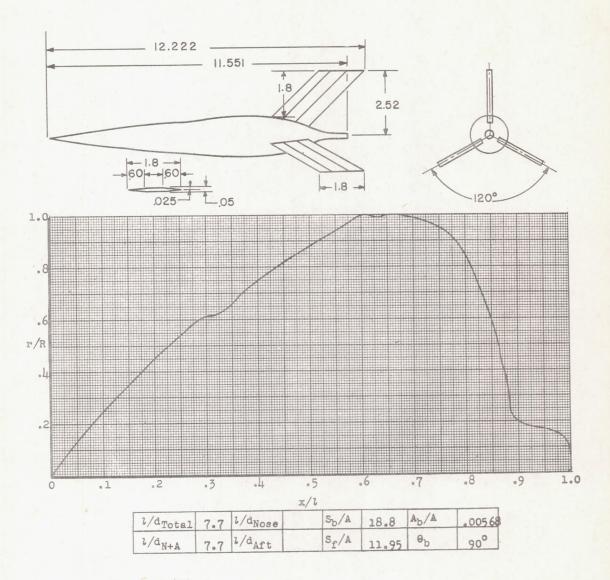


Figure 142. - Concluded.



Designation: 137

Test: Helium Gun

Figure 143.

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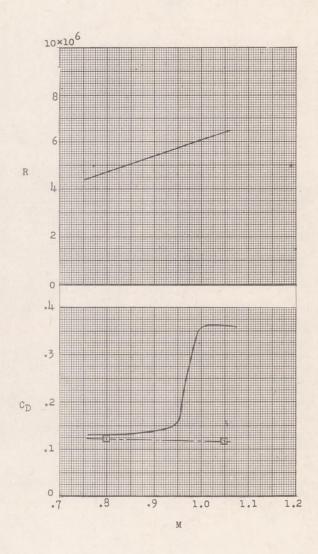
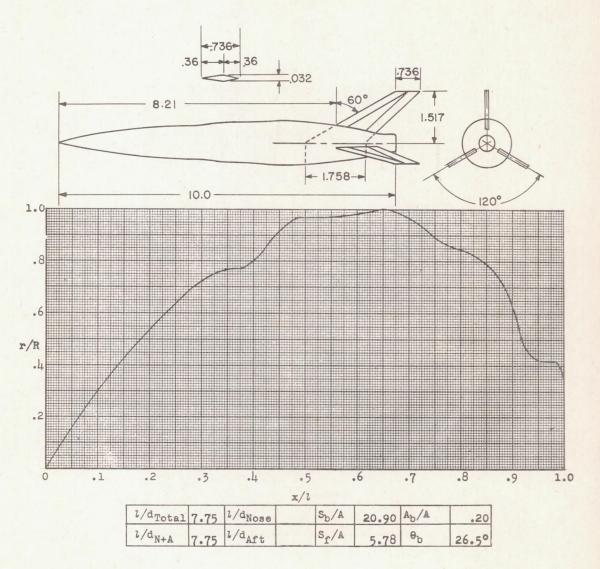


Figure 143. - Concluded.



Designation: 138

Test: Helium Gun

Remarks: Remarks for configuration 125 (fig. 131) may apply to these models also.

Figure 144.

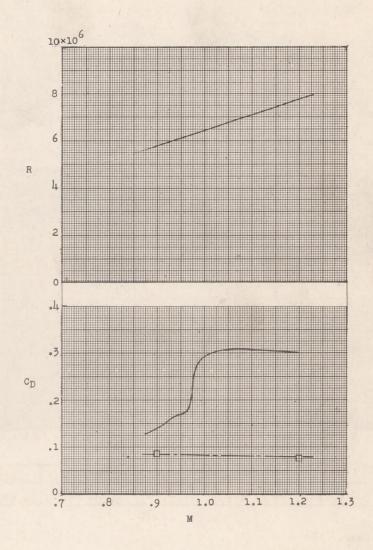
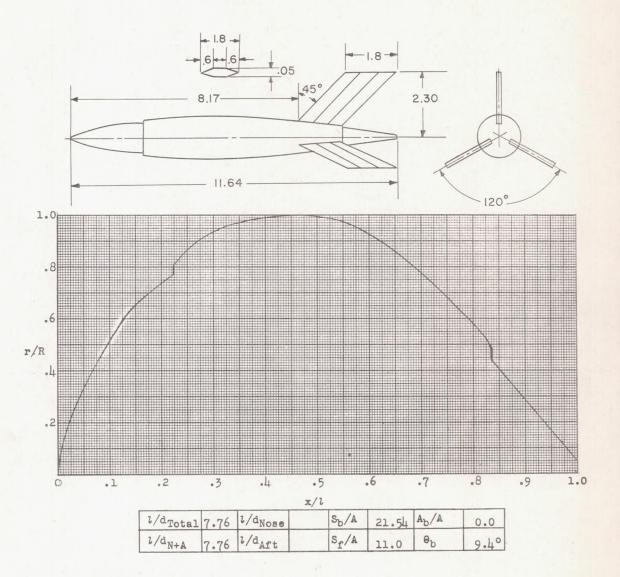


Figure 144.- Concluded.



Test: Helium Gun

Remarks: Remarks for configuration 125 (fig. 131) may apply to these models also.

Figure 145.

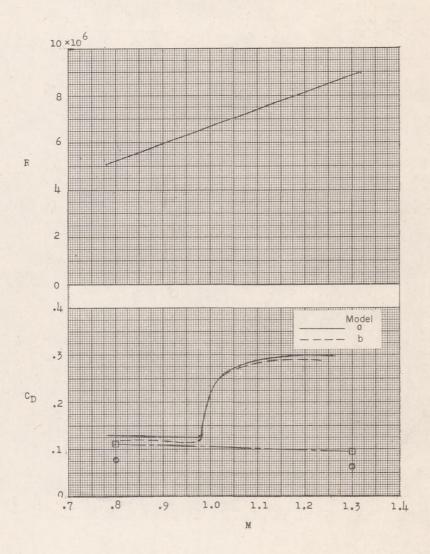


Figure 145.- Concluded.

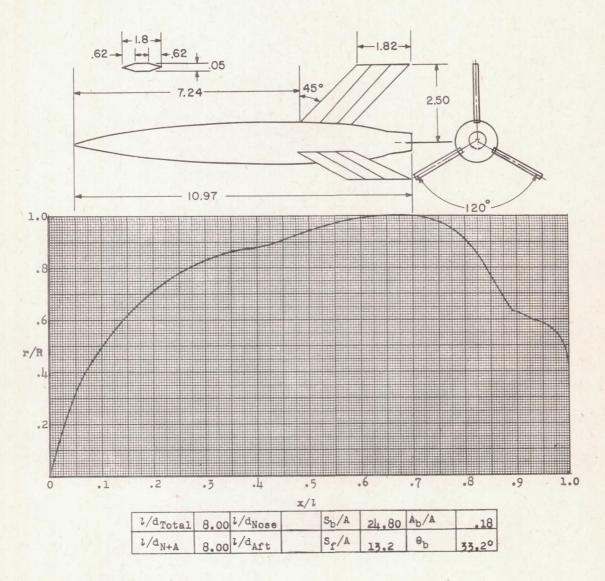


Figure 146.

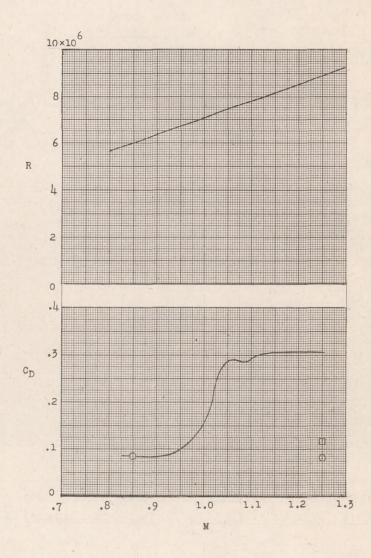


Figure 146.- Concluded.

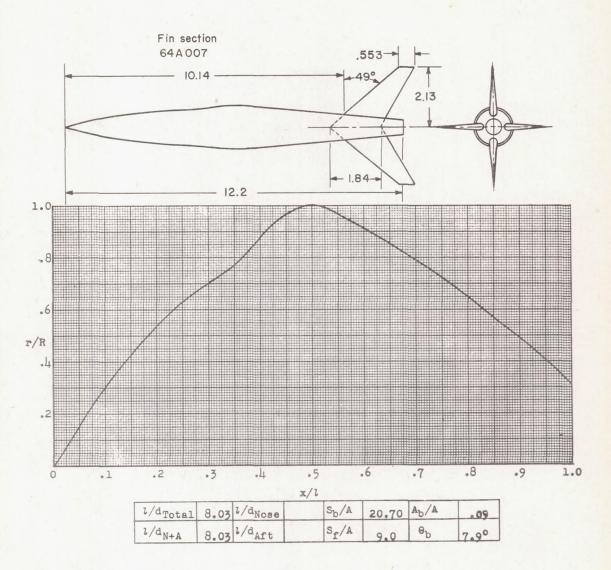


Figure 147.

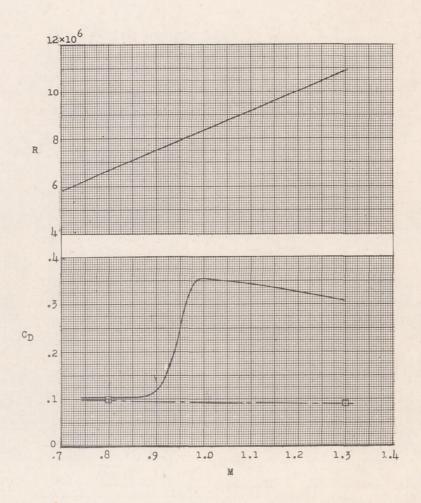


Figure 147. - Concluded.

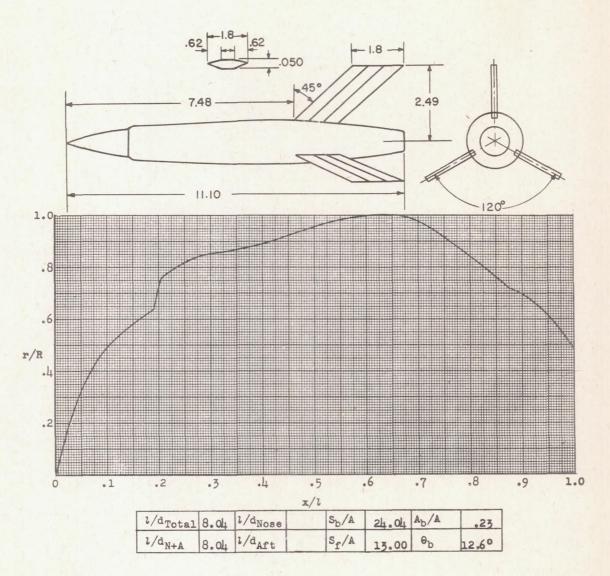


Figure 148.

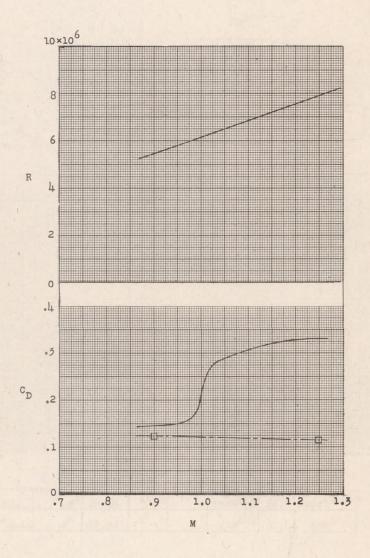


Figure 148. - Concluded.

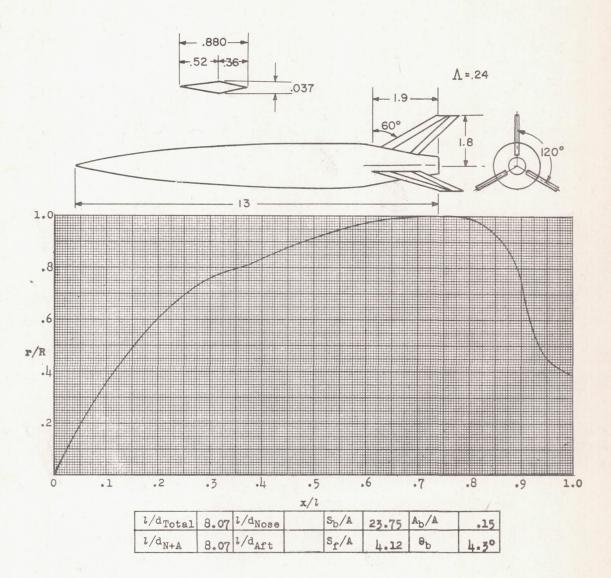


Figure 149.

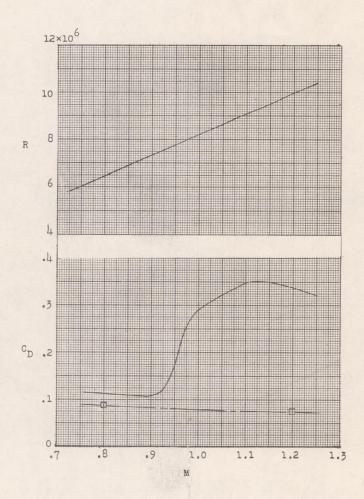
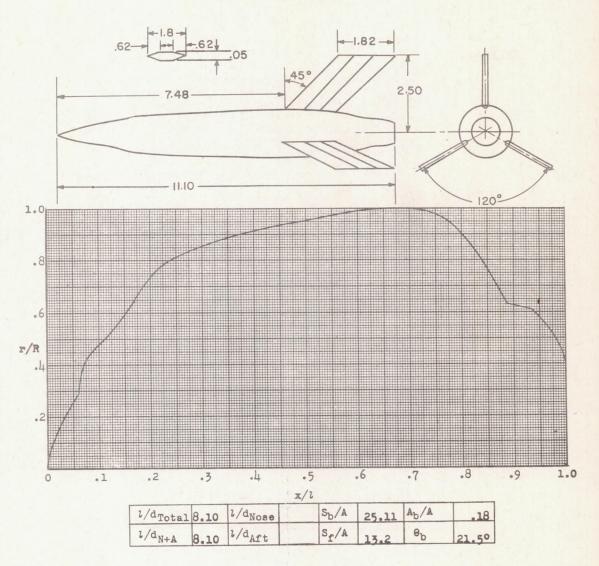


Figure 149. - Concluded.



Designation: 144

Test: Helium Gun

Figure 150.

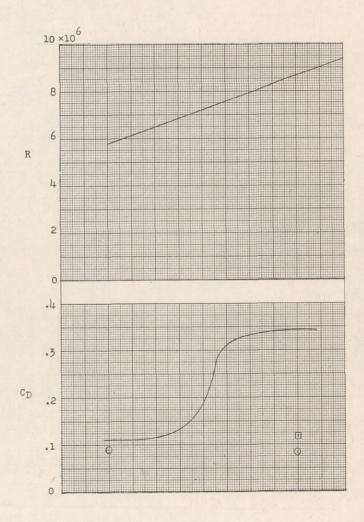


Figure 150. - Concluded.

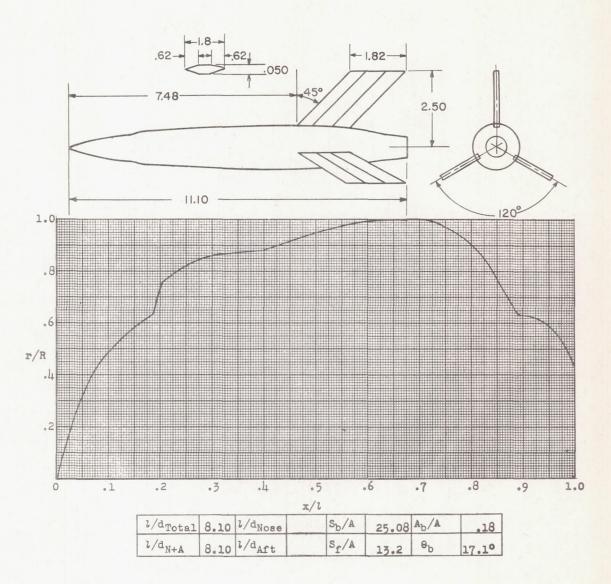


Figure 151.

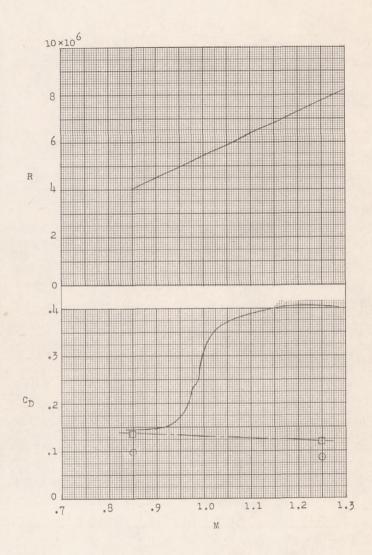
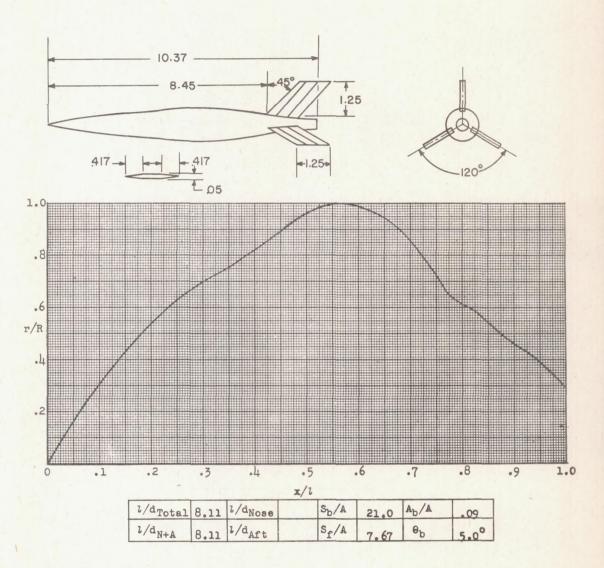


Figure 151. - Concluded.



Designation: 146

Test: Helium Gun

Figure 152.

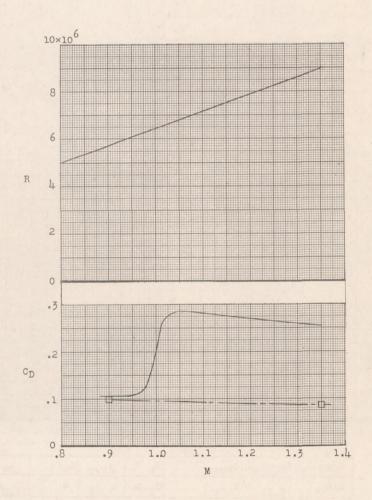
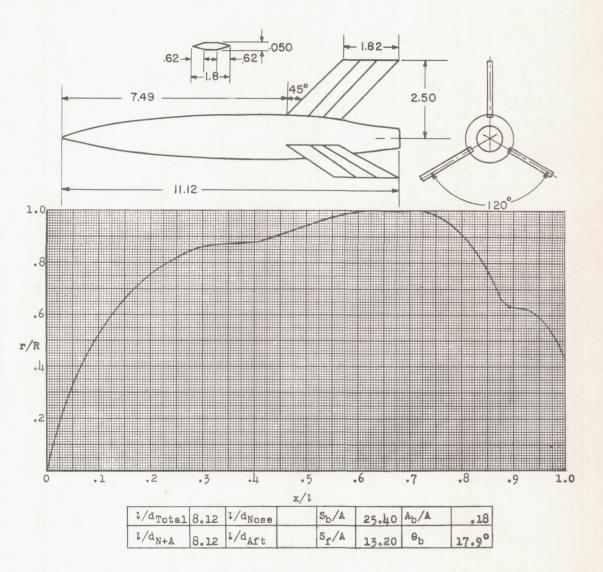


Figure 152. - Concluded.



Designation: 147

Test: Helium Gun

Figure 153.

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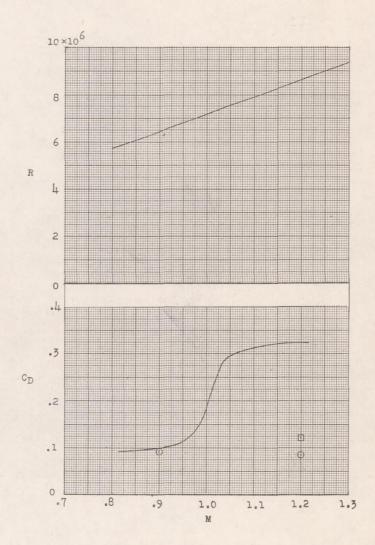


Figure 153. - Concluded.

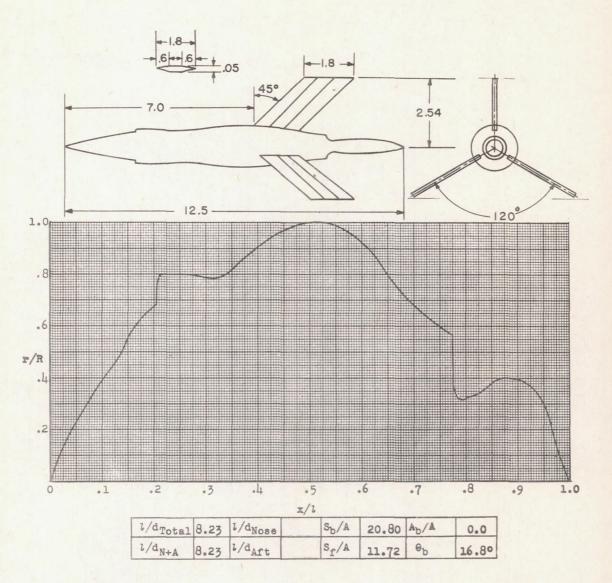


Figure 154.

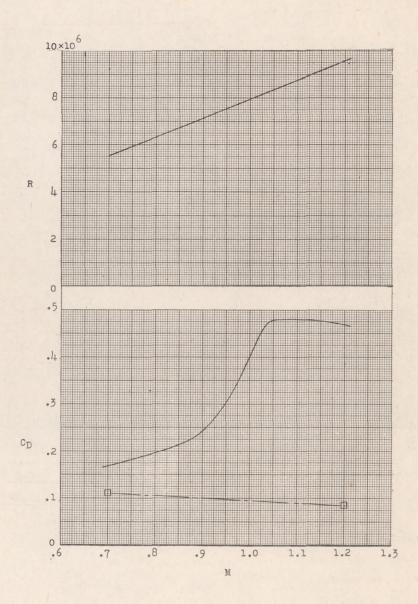


Figure 154. - Concluded.

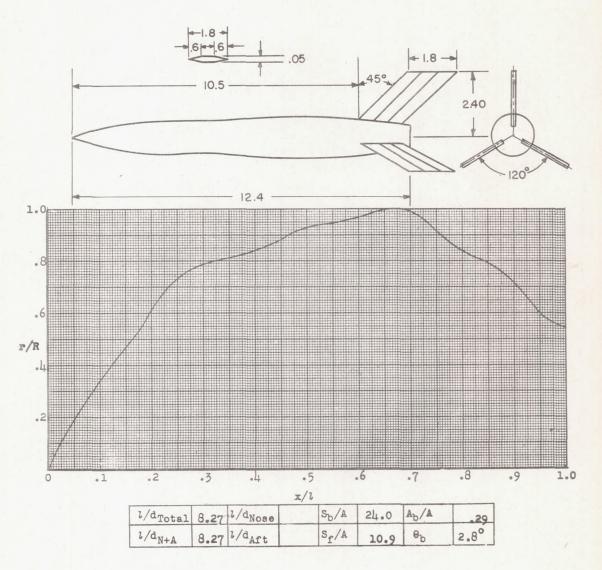


Figure 155.

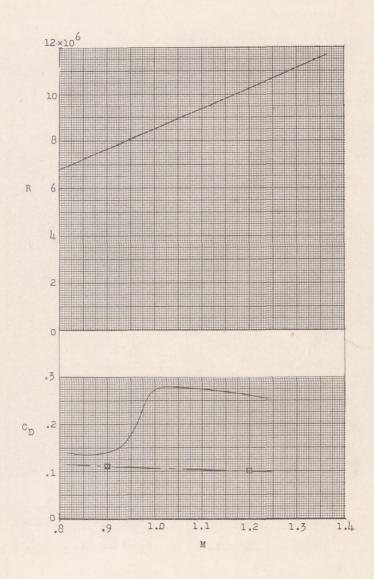


Figure 155. - Concluded.

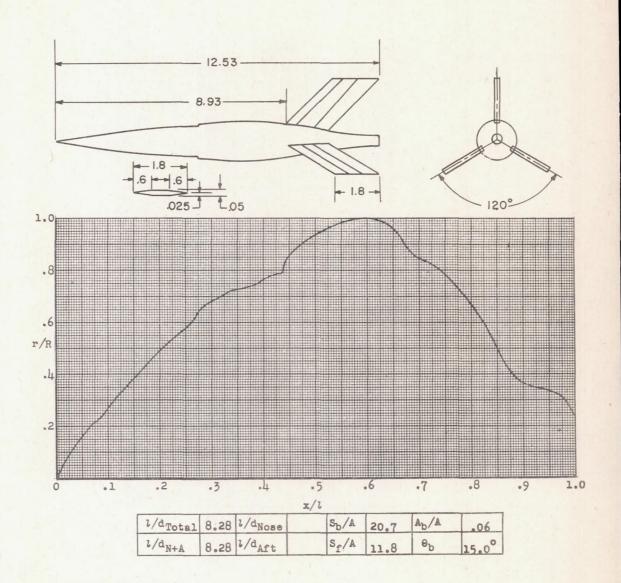


Figure 156.

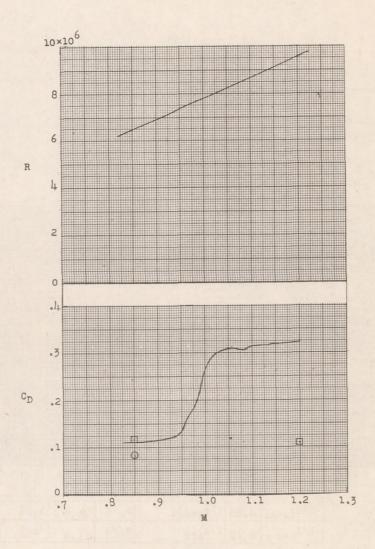
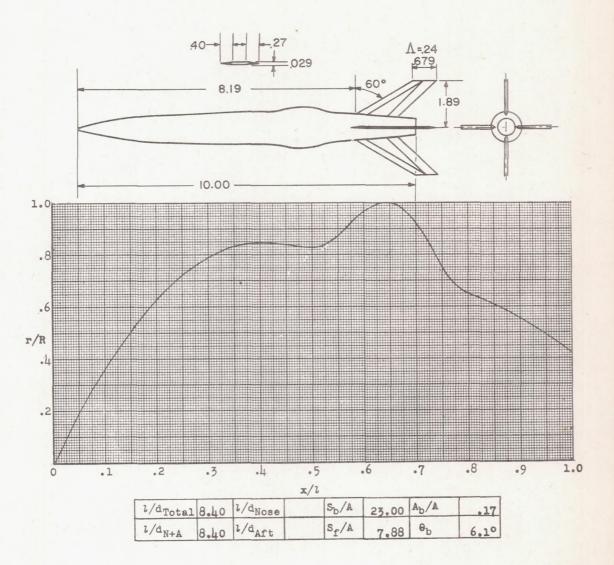


Figure 156. - Concluded.



Test: Helium Gun

Figure 157.

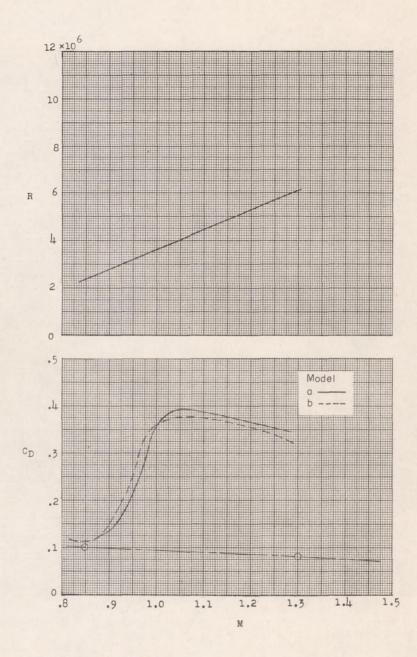


Figure 157. - Concluded.

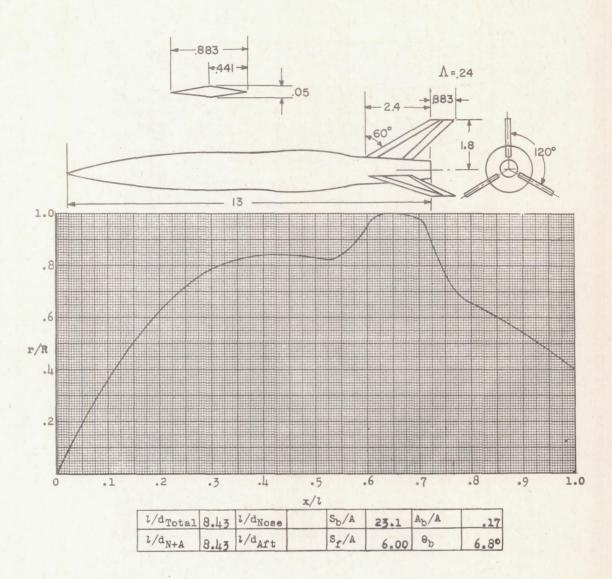


Figure 158.

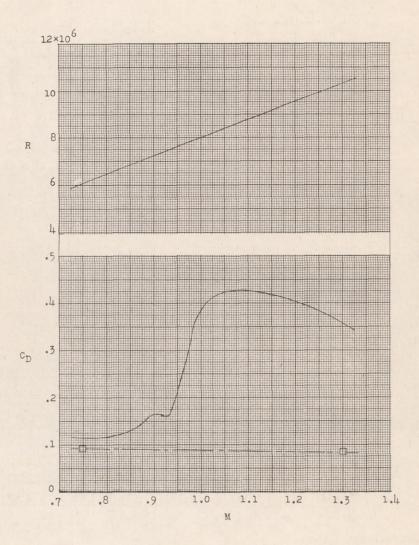


Figure 158. - Concluded.

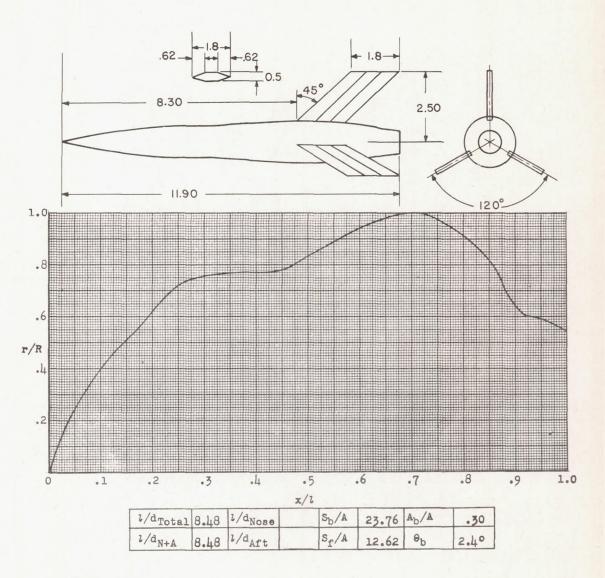


Figure 159.

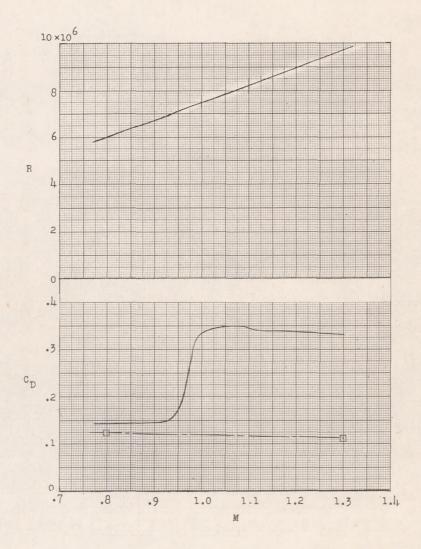


Figure 159. - Concluded.

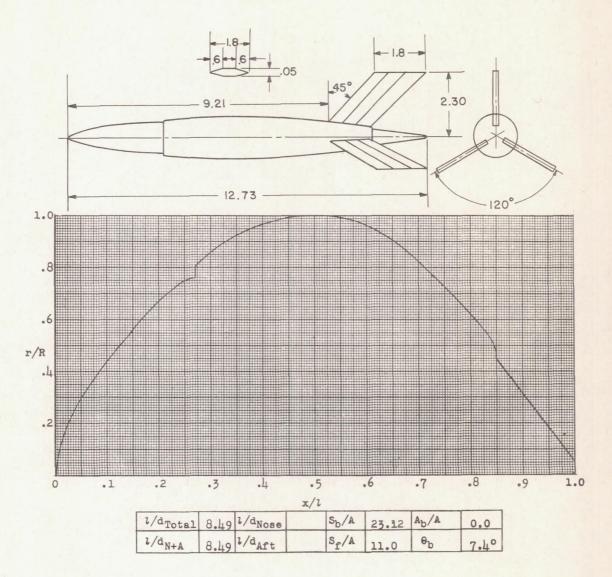


Figure 160.

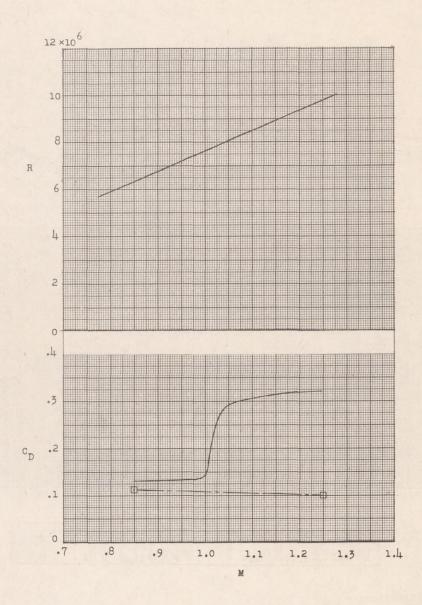


Figure 160.- Concluded.

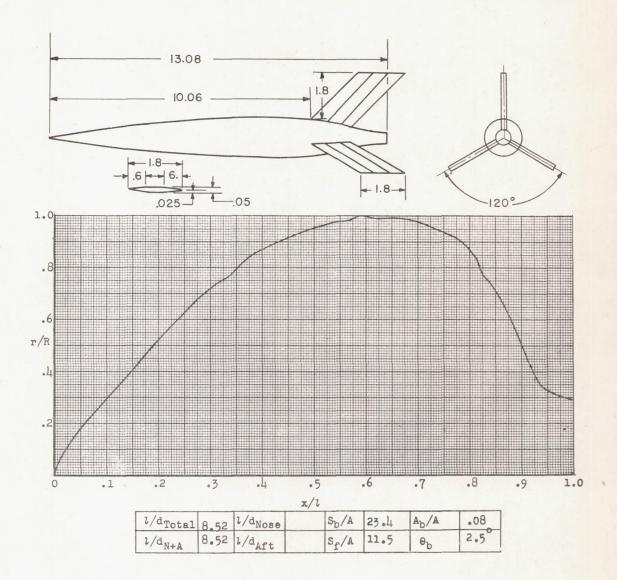


Figure 161..

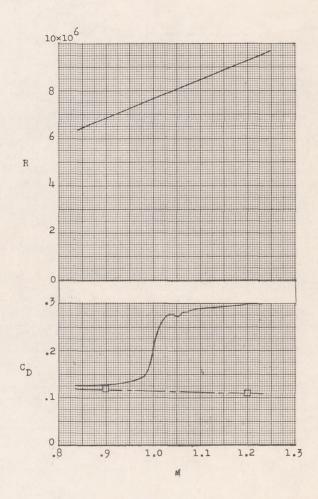
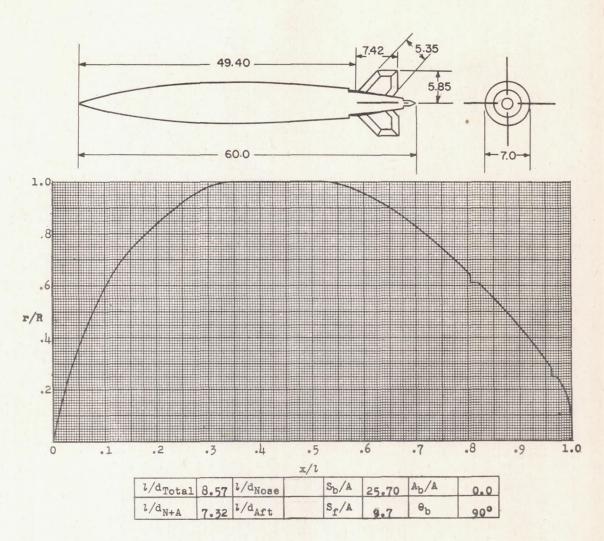


Figure 161.- Concluded.



Test: Rocket

Figure 162.

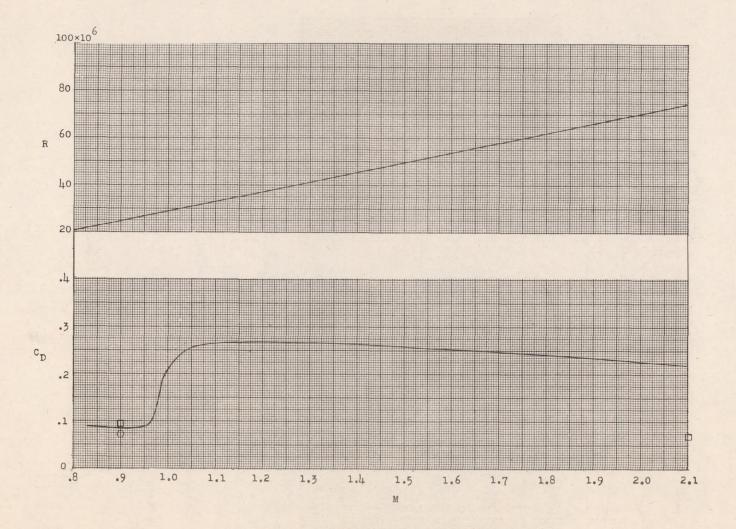


Figure 162.- Concluded.

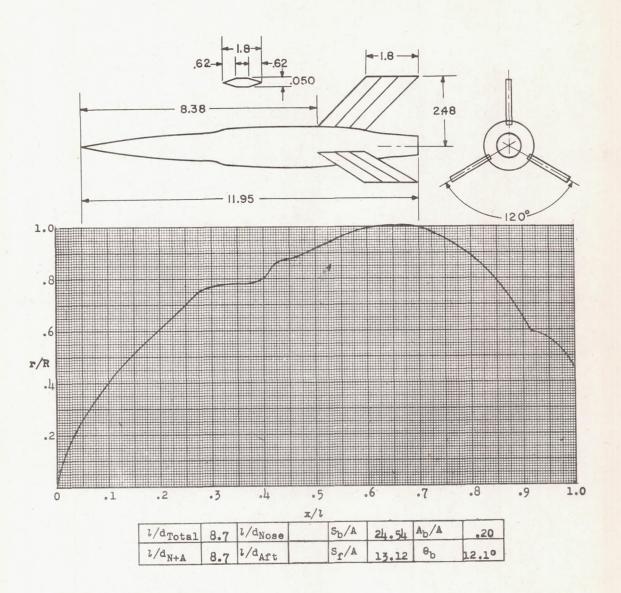


Figure 163.

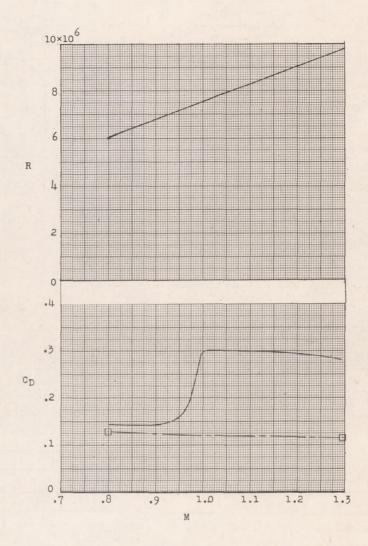


Figure 163.- Concluded.

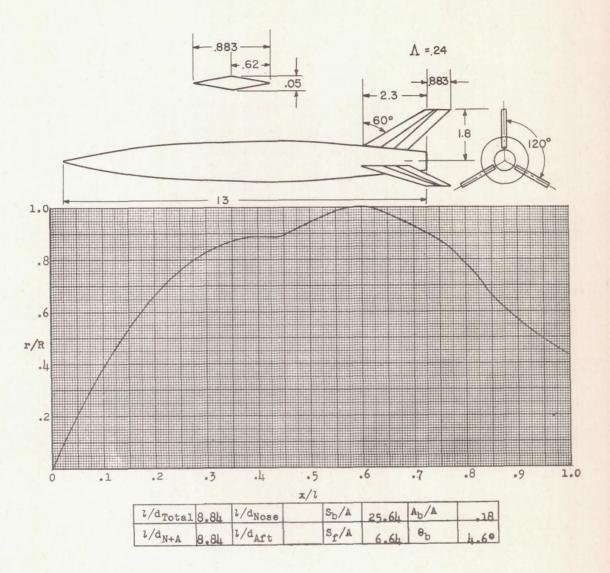


Figure 164.

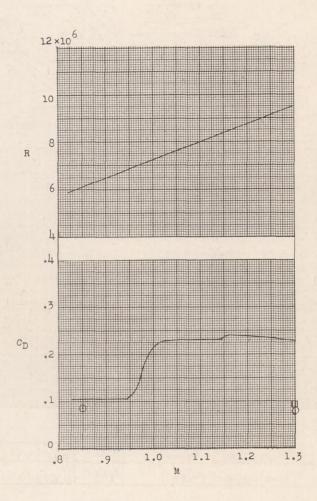


Figure 164. - Concluded.

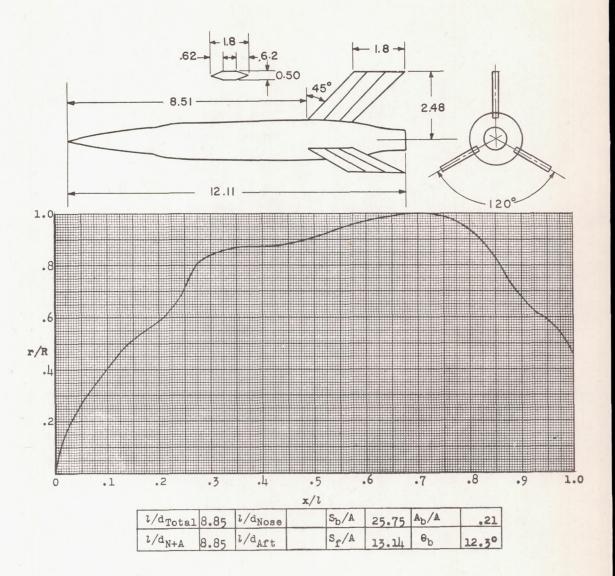


Figure 165.

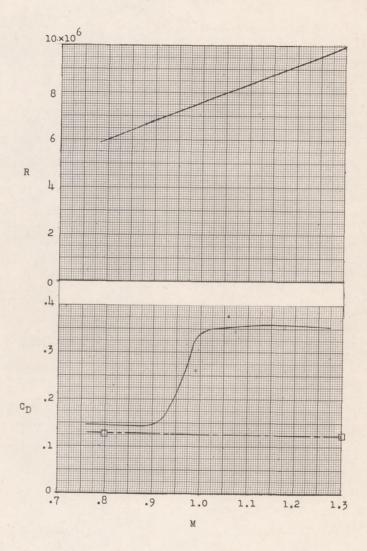
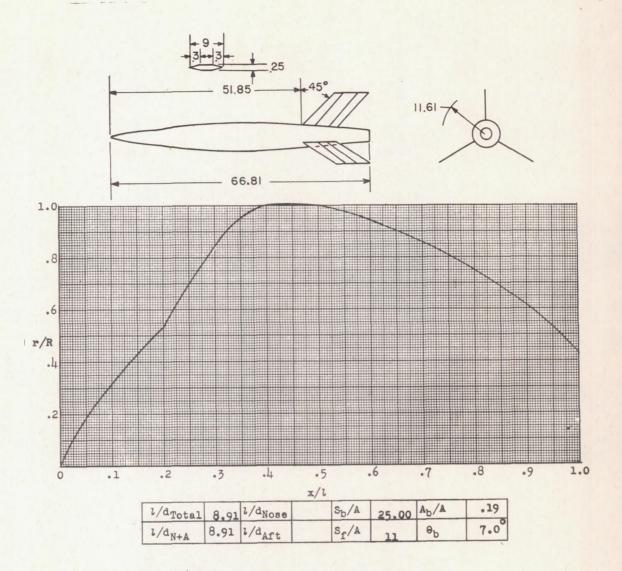


Figure 165.- Concluded.



Test: Rocket

Remarks: Parabolic afterbody.

Figure 166.

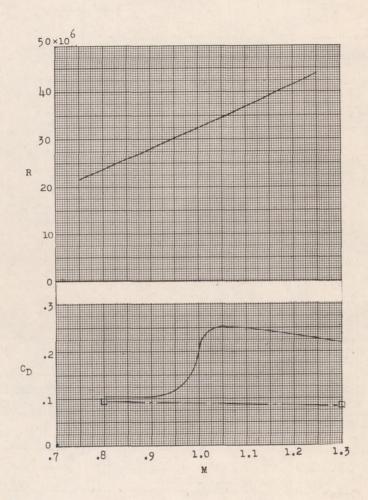
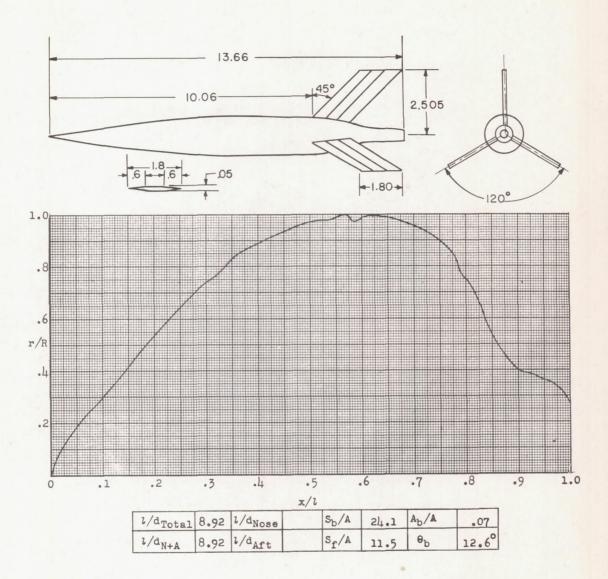


Figure 166. - Concluded.



Designation: 161

Test: Helium Gun

Figure 167.

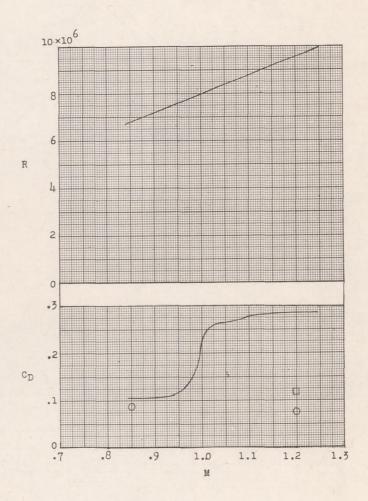


Figure 167.- Concluded.

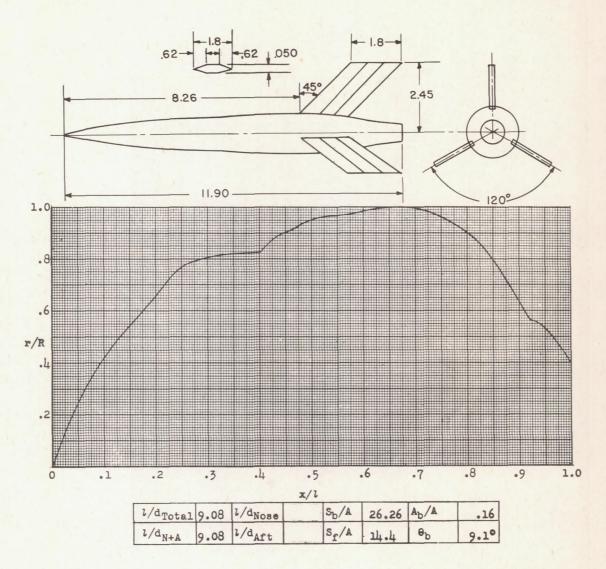


Figure 168.

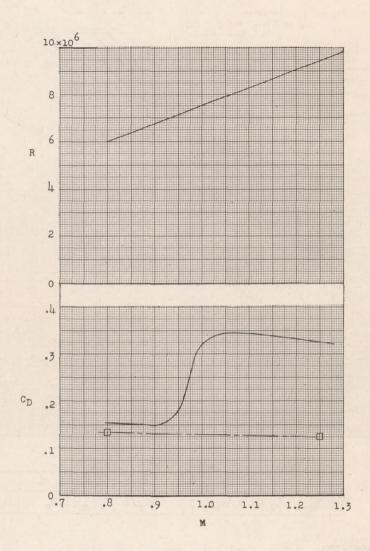
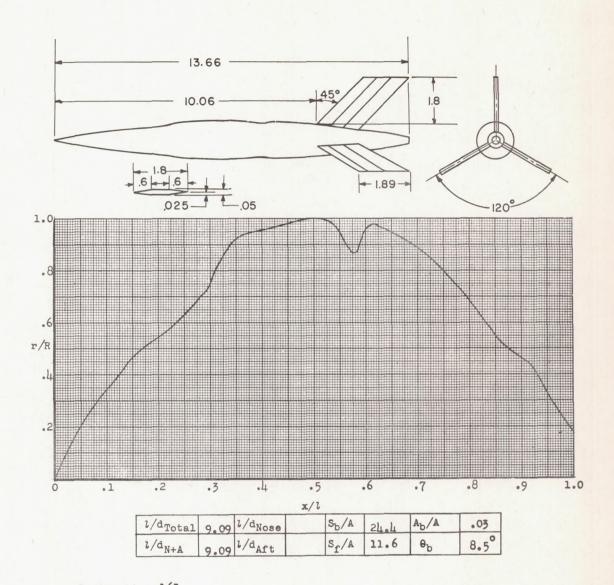


Figure 168. - Concluded.



Designation: 163

Test: Helium Gun

Figure 169.

345

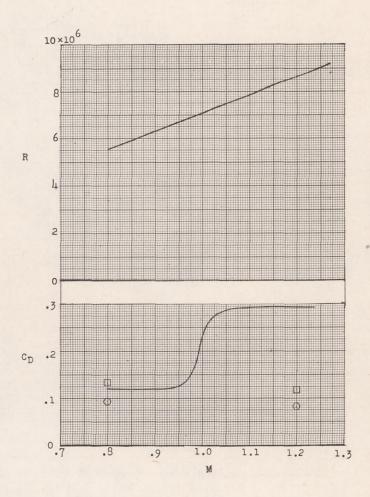


Figure 169.- Concluded.

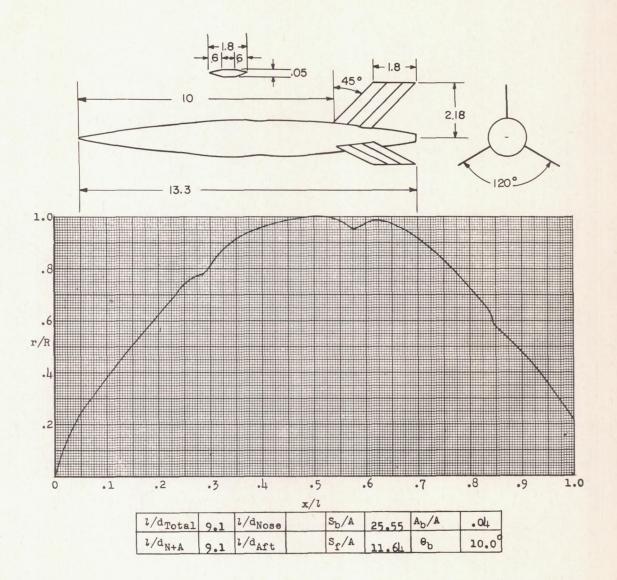


Figure 170.

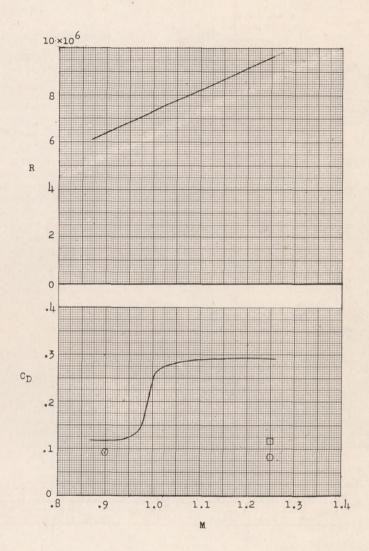


Figure 170. - Concluded.

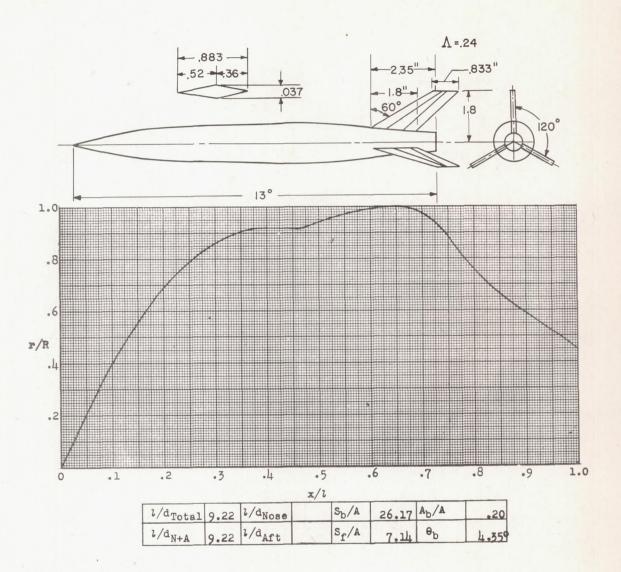


Figure 171.

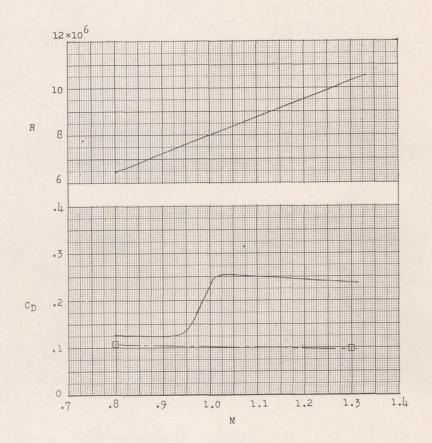


Figure 171. - Concluded.

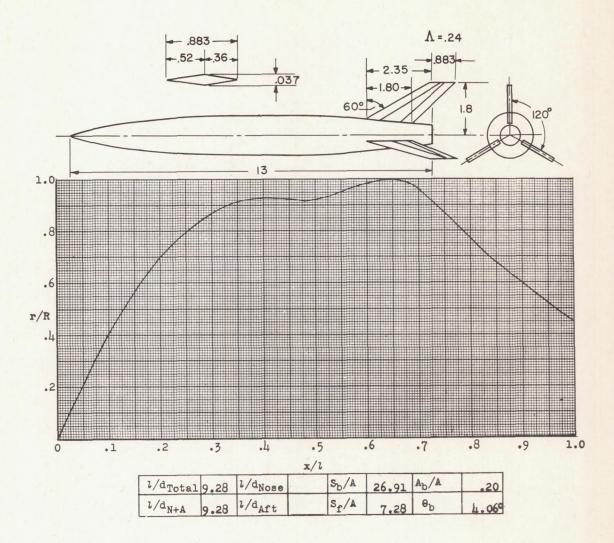


Figure 172.

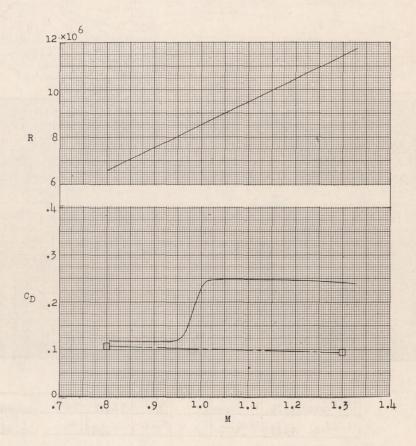


Figure 172. - Concluded.

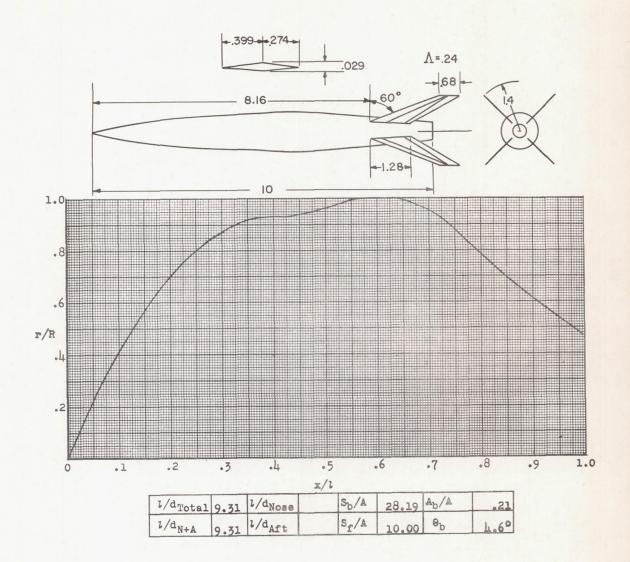


Figure 173.

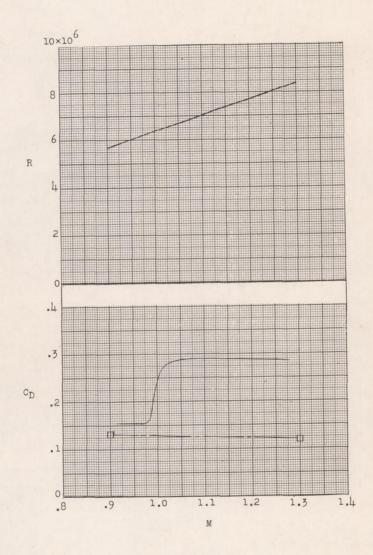
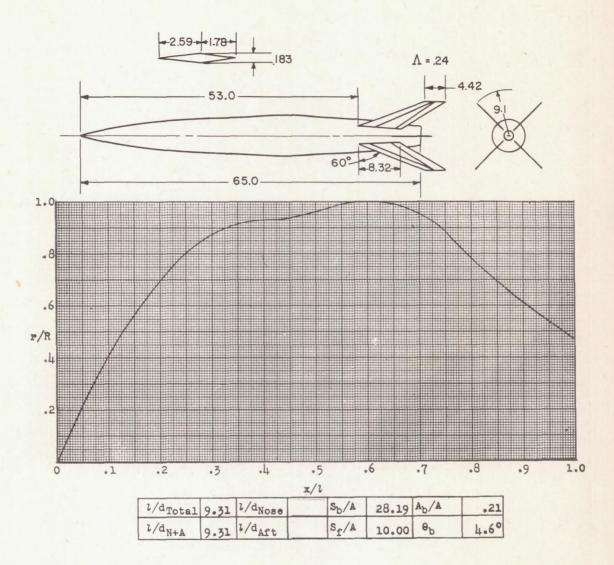


Figure 173. - Concluded.



Test: Rocket

Figure 174.

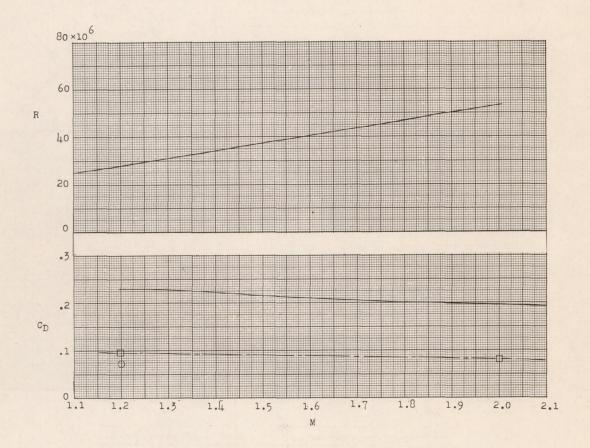
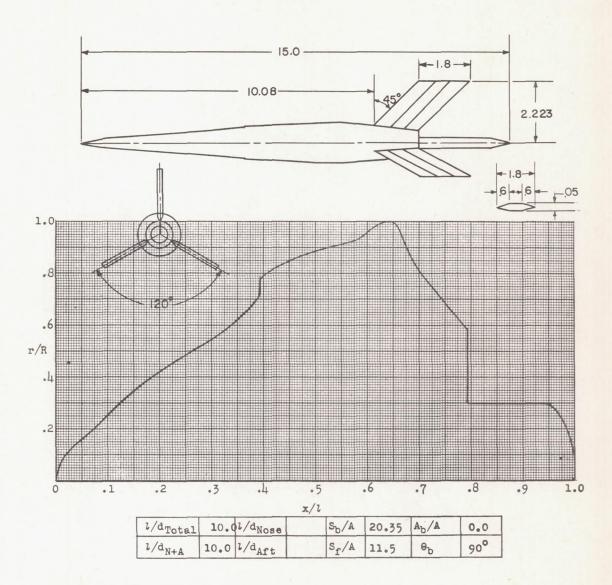


Figure 174. - Concluded.



Designation: 169

Test: Hellum Gun

Figure 175.

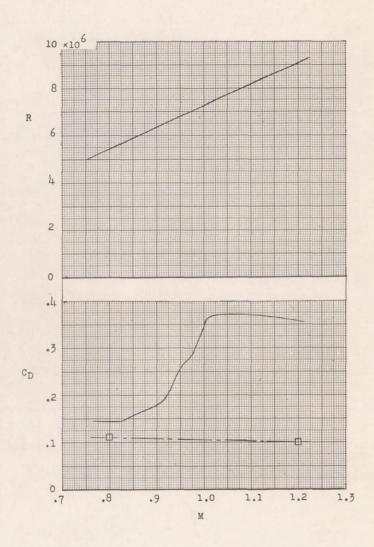
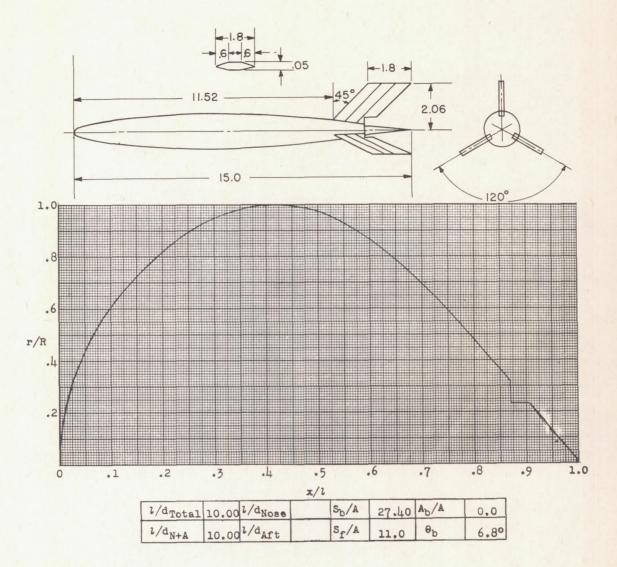


Figure 175. - Concluded.



Test: Helium Gun

Remarks: Apparently there was an appreciable length of laminar flow on the body of this model.

Figure 176.

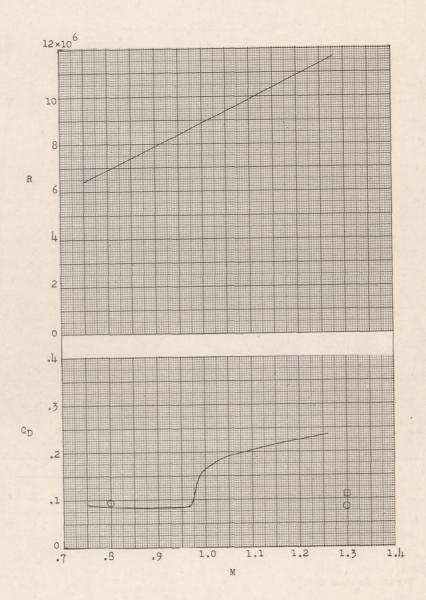
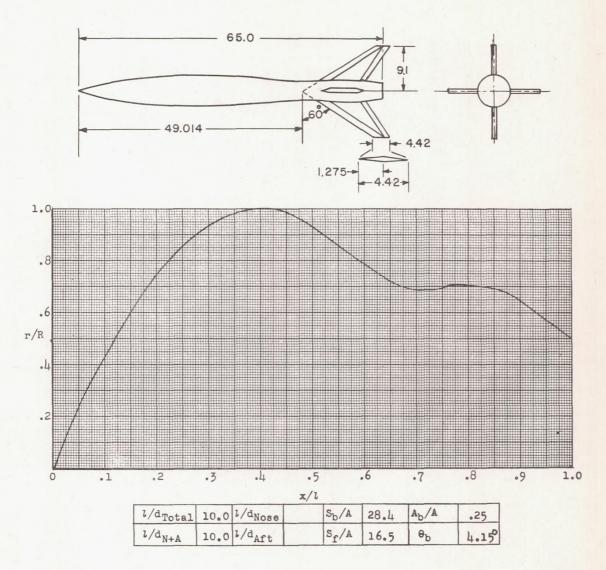


Figure 176. - Concluded.



Designation: 171

Test: Rocket

Figure 177.

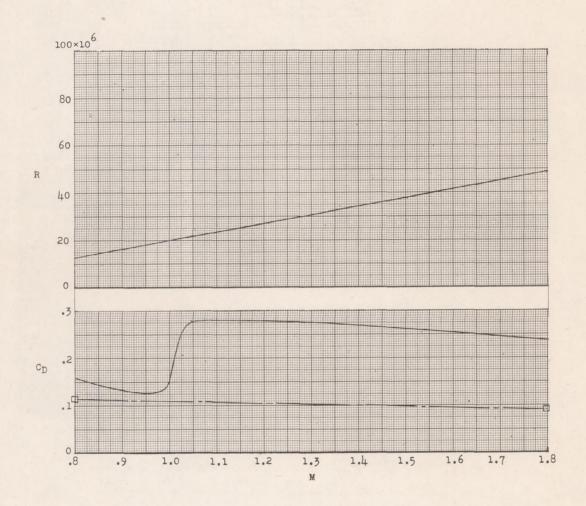
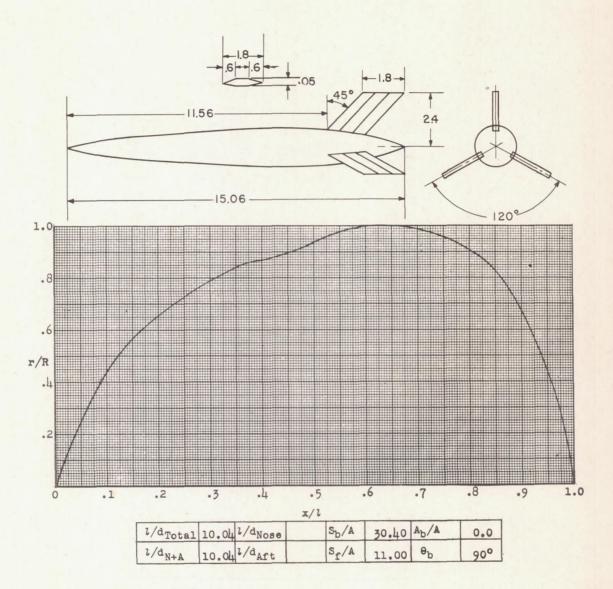


Figure 177. - Concluded.



Designation: 172

Test: Helium Gun

Figure 178.

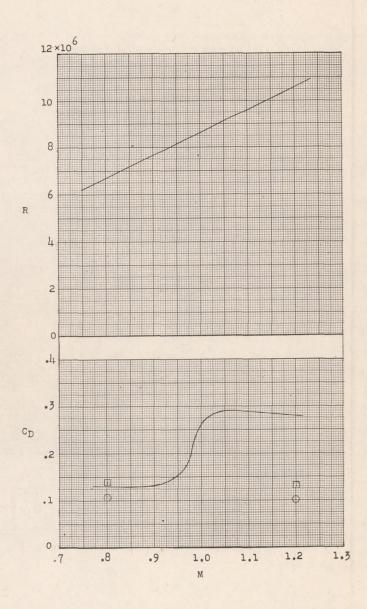
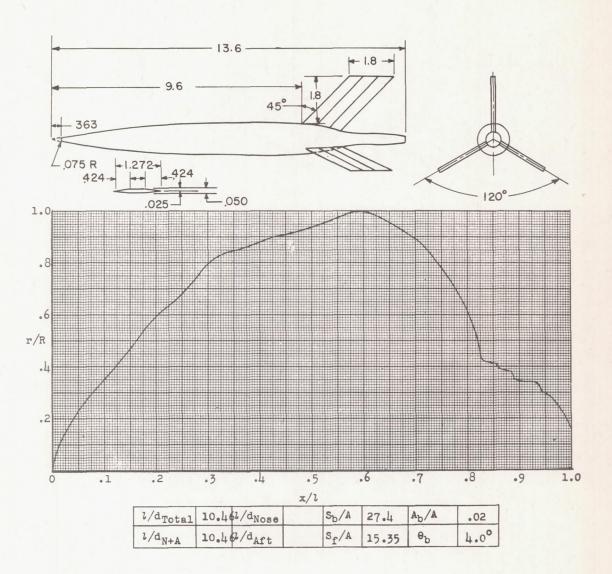


Figure 178.- Concluded.



Designation: 173

Test: Helium Gun

Figure 179.

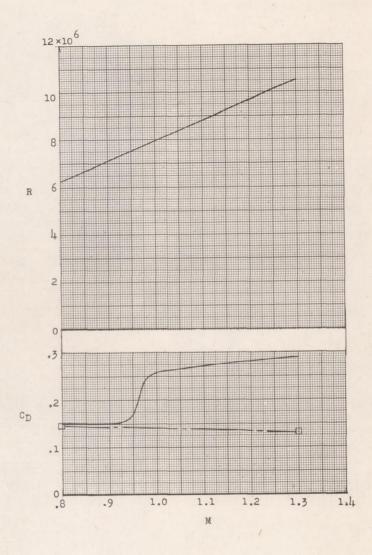
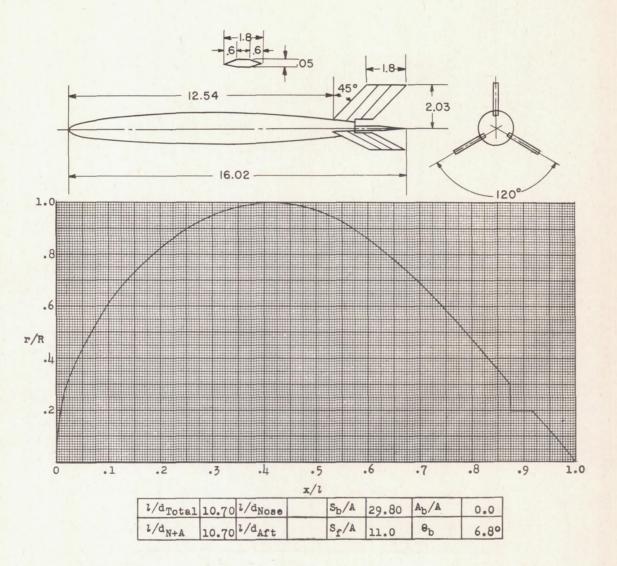


Figure 179. - Concluded.



Designation: 174

Test: Helium Gun

Figure 180.

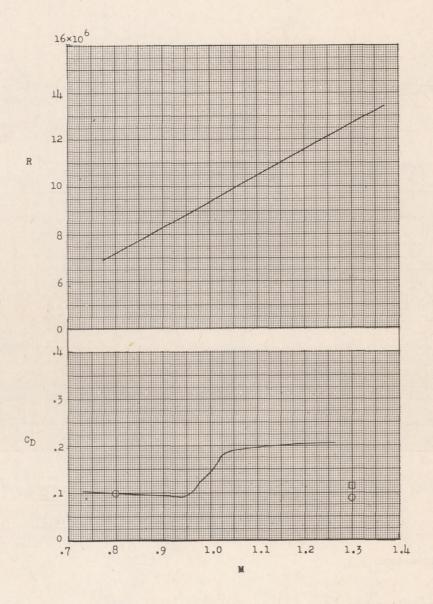
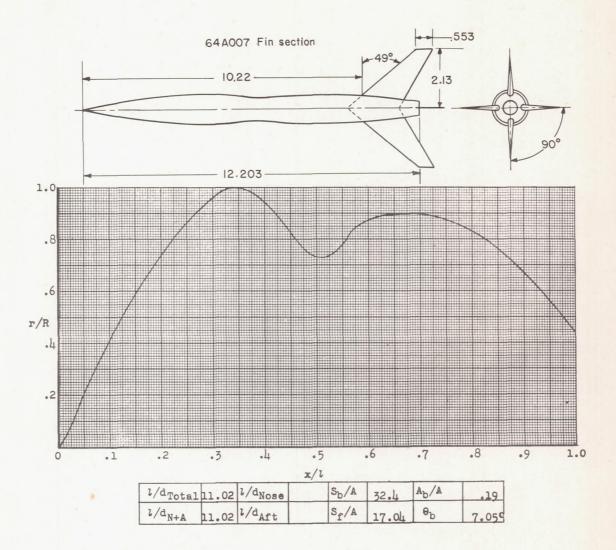


Figure 180. - Concluded.



Designation: 175

Test: Helium Gun

Figure 181.

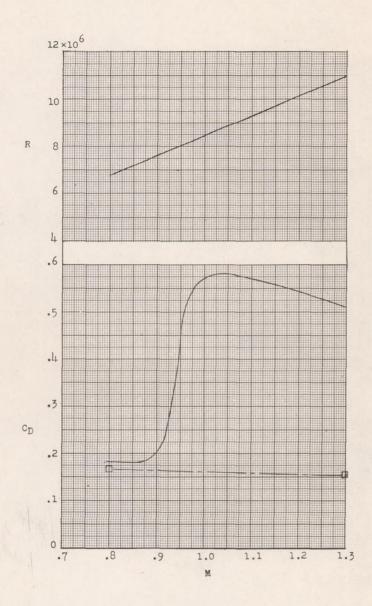
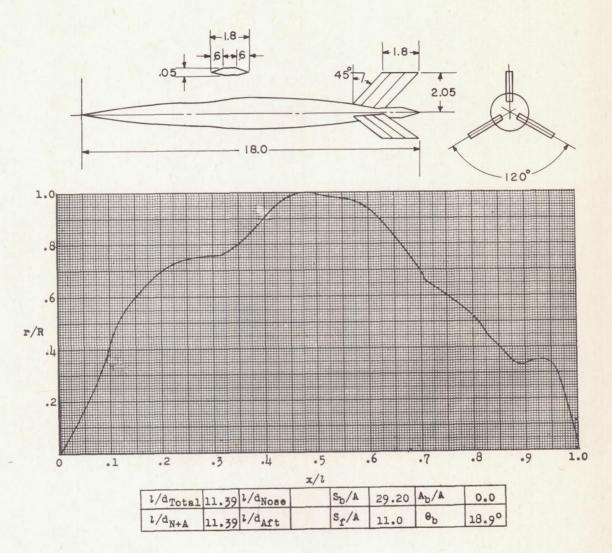


Figure 181. - Concluded.



Designation: 176

Test: Helium Gun

Figure 182.

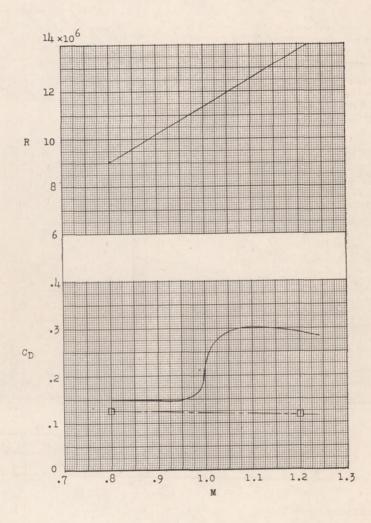
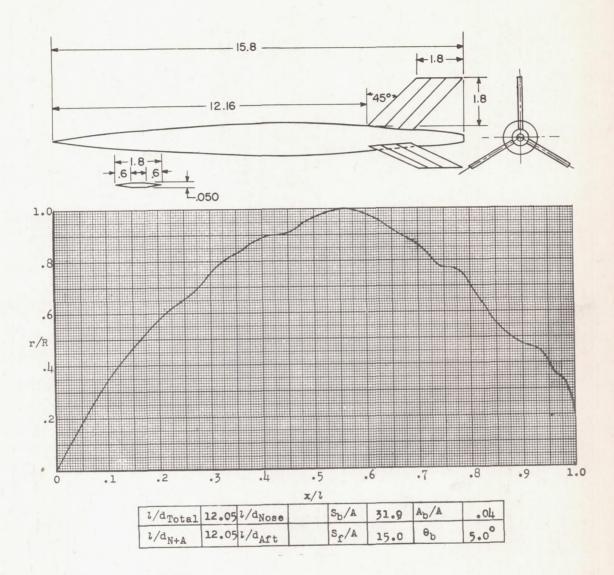


Figure 182.- Concluded.



Designation: 177

Test: Helium Gun

Figure 183.

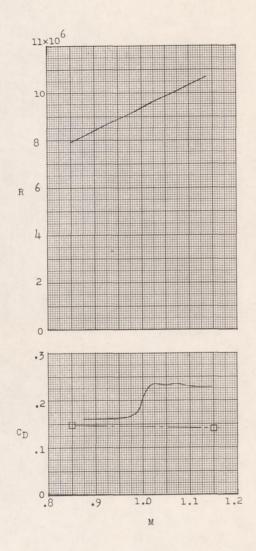


Figure 183. - Concluded.